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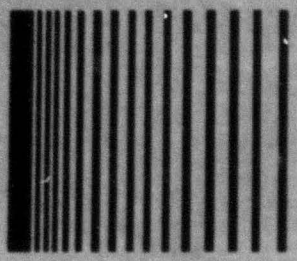

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SVIC NOTES

STRESS SCREENING OF SHIPBOARD MOUNTED ELECTRONICS

The Department of Defense has been using stress screening as a means for improving the reliability of electronic equipment. The stresses which have been found to be the most useful are temperature cycling and random vibration. The basic reasoning behind this method is as follows.

When failure rates are examined during the life cycle of an electronic system, it results in the well known "bathtub curve." The bathtub curve plots the number of failures as a function of time over the life of a system. During a system's life cycle, the failure rate is high in its early life, low and constant in mid-life and then increases rapidly to higher values as the system wears out. Stress screening precipitates out the early failures and puts the system into the mid-life area where its failure rate is the lowest. The pay-off of the stress screening is that the screened equipment experiences its lowest failure rate when put into service.

There is no question that this scenario is valid for avionics. There is ample documentation to prove its cost effectiveness. There is, however, a conceptual problem when you apply these techniques to shipboard mounted electronics.

The conceptual problems come about when one examines the shipboard random vibration environments. They are quite low. This isn't surprising. Anyone familiar with transportation environments knows that about the softest ride attainable is onboard a ship. With avionics, the in-service random vibration levels are not greatly different than the stress screening levels, so no one complains much when the boxes are stress screened. They have designed their equipment to survive the in-service environment so the stress-screen doesn't bother them. For shipboard-mounted electronics, the measured random vibration levels are so low that it becomes difficult to control vibration test equipment to these low amplitudes.

One should not design a piece of equipment to just barely survive these low vibration levels. Equipment designed this way wouldn't be rugged enough to survive other, more severe shipboard environments which the equipment will see during its life. First, it must survive the transportation and handling environment in order to go from the manufacturer to its final destination onboard ship. It must also survive the shipboard shock environment. By the time a manufacturer has designed the equipment to survive these two environments, it will be quite rugged.

In practice, stress screening uncovers few inherent design inadequacies. Most of the failures are due to defective parts and faulty workmanship. Therefore, you would not design your equipment to pass a stress screening test! The best way to design your way through a stress screening test is to design better quality control procedures into the manufacturing plant!

In conclusion, I would say stress screening can and should be used to improve the reliability of shipboard mounted electronics. What is still unclear at this time, however, is how to establish the appropriate screening levels. ! will address this topic in an editorial at a later date.

J.G.S.

EDITORS RATTLE SPACE

COMPUTER AIDED TESTING (CAT)

In an era where computer aided design (CAD) and computer aided manufacturing (CAM) are the subject of many technical papers I am surprised at the lack of written work on the use of computers in testing. Computer aided testing (CAT) was initiated over 15 years ago with computer controlled shakers. Today, computers are used in almost all forms of testing -- from excitation control to data analysis, storage, and manipulation. Despite the wide range of applications of the computer to testing I have yet to read a paper that contains an overview of CAT.

Computer aided testing began with the use of large and small computers to control shakers for environmental testing. Specific excitation waveforms were generated to simulate an environment or to duplicate a damage level. Environmental vibration testing has served both the military and industrial community well -- saving millions of dollars through effective testing and screening of new and old products.

The advent of the fast Fourier transform (FFT) algorithm opened the field of data analysis to the computer. Spectrum analysis using the computer has replaced the time compression and filter type analyzers in popularity because of the versatility of the FFT algorithm and dedicated hardware. Software associated with the FFT has taken many imaginative forms. It appears that this area will continue to grow as the ingenuity of design engineers interfaces with the requirements of users.

While the computer had a minor role in test set-up, selection, and planning and the selection of sensor locations previously, more elaborate preliminary "tests" are now conducted on the computer. Mathematical simulation is used to perform these tasks. Sensor locations are evaluated with respect to mode shapes. Sensitivity of vibration response to controlled excitation is evaluated prior to and during the design of test fixtures and test specimen.

Finally the computer provides a logical means for storage, manipulation, and categorization of test data.

CAT has been in existence for many years - serving the requirements of experimentalists without a lot of publicity or published works. An article on the various applications of CAT would be interesting and may lead to further development of the field.

R.L.E.

FATIGUE DESIGN OF MACHINE ELEMENTS

C. Bagci*

Abstract. ***This is the first of a series of literature review articles on the state of the art of fatigue design of machine elements. These articles describe recent developments and research results and their applications for industrial designs. The following are emphasized: new forms of design equations that are suitable for computer-aided-designs, factors affecting fatigue life and their incorporation in design equations, and evaluation of proposed criteria for the fatigue design of machine members experiencing complex stress fields. This article summarizes the historical background of fatigue design of machine elements and reviews recent forms of data and fatigue design equations.***

All machine design problems related to strength are problems of fatigue because machine members are always subjected to time-dependent forces. Ever since it was recognized that machine parts can fail at stress levels much lower than their yield strength due to alternating stresses, machine designers have tried to formulate design equations that represent available data and to guide the design of machine elements for fatigue life.

Wohler [1] was the first to gather reliable fatigue test data. He showed that the number of cycles to failure depends on alternating stress, or stress range, S_a. S_a decreased as the number of stress cycles N increased; this relationship is the basis for the S-N diagram when no mean stress exists. Wohler was also the first to collect fatigue test data using mean stress and to show that S_a decreases for a given stress cycle to failure as the mean stress S_m increases.

Based on Wohler's fatigue data with no stress concentration effect, Gerber [2] proposed the following second order relationship to represent the failure value of the alternating stress S_{af} for a given number of stress cycle N at which the S-N diagram predicts S'_e as the failure value (or fatigue strength) when $S_m = 0$.

$$S_{a_f} = S'_e\left[1 - \left(\frac{S_{m_f}}{S_u}\right)^2\right] \tag{1}$$

S_u is the ultimate strength of the material, S_{mf} is the failure value of the mean stress. S'_e is in general considered the endurance limit of the material, especially for carbon steel, for $N \geq 10^6$ cycles.

Goodman [3] proposed a more conservative straight line relationship.

$$S_{a_f} = S'_e\left[1 - \frac{S_{m_f}}{S_u}\right] \tag{2}$$

Yielding of structural members under static loading on a local or submacroscopic scale is considered harmless. Goodman recognized, however, that machine members should not be loaded, even under static conditions, beyond their yield strength to the point that permanent deformation occurs. He therefore modified equation (2) by introducing a second zone defined by

$$S_{a_f} = S_y\left[1 - \frac{S_{m_f}}{S_y}\right] \tag{3}$$

S_y is the yield strength of the material. Soderberg [4] introduced the more conservative straight line form of the equation:

$$S_{a_f} = S'_e\left[1 - \frac{S_{m_f}}{S_y}\right] \tag{4}$$

Experiments have been carried out with notched fatigue specimens and specimens whose fatigue strength has been reduced under combined loading (bending and torsion). The data distribution follows somewhat the form defined by equation (1) except

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that S_e' is replaced by the reduced fatigue strength S_e defined [5-13] by

$$S_e = C_f S_e' \tag{5}$$

C_f is the overall fatigue strength reduction factor. At present, defining its components is a major research topic in the study of the fatigue of metals and machine elements.

Results of recent research on fatigue of carbon steels with notched specimens [14] show that failure value of the alternating stress is best approximated by

$$S_{a_f} = S_e\left[1 - \left(\frac{S_{m_f}}{S_u}\right)^2\right]^{1/a} \tag{6}$$

where a is a material constant dependent on such factors as material properties, geometry, and dimensions of the notch and the loading. An extensive amount of data for a will be required to make equation (6) useful for fatigue design. The Gerber line is conservative and leads to overdesign.

Figure 1 shows the plots of equations (1) - (6) for steel; S_e = 114.45 Mpa (16.6 k_{si}), S_u = 565.33 Mpa (82 k_{si}), and S_y = 482.6 Mpa (70 k_{si}). An a value of 2.606 for AISI 4340 steel for a geometric stress concentration factor of 2.36, is used [14] to plot equation (6). The Kececioglu line defined by equation (6) must be limited by the yield line given by equation (3) if it is to be used to design machine elements. Introduction of the yield line of equation (3) introduces two design zones; the slope of the load line is tested to determine the applicable zone.

Bagci [15, 16] recently proposed a fourth order line to define the fatigue failure surface that is limited by the yield strength of the material. The equation is

$$S_{a_f} = S_e\left[1 - \left(\frac{S_{m_f}}{S_y}\right)^4\right] \tag{7}$$

Equation (7), which is plotted in Figure 1, defines two design zones in one and represents fatigue data very well. It takes the following form when

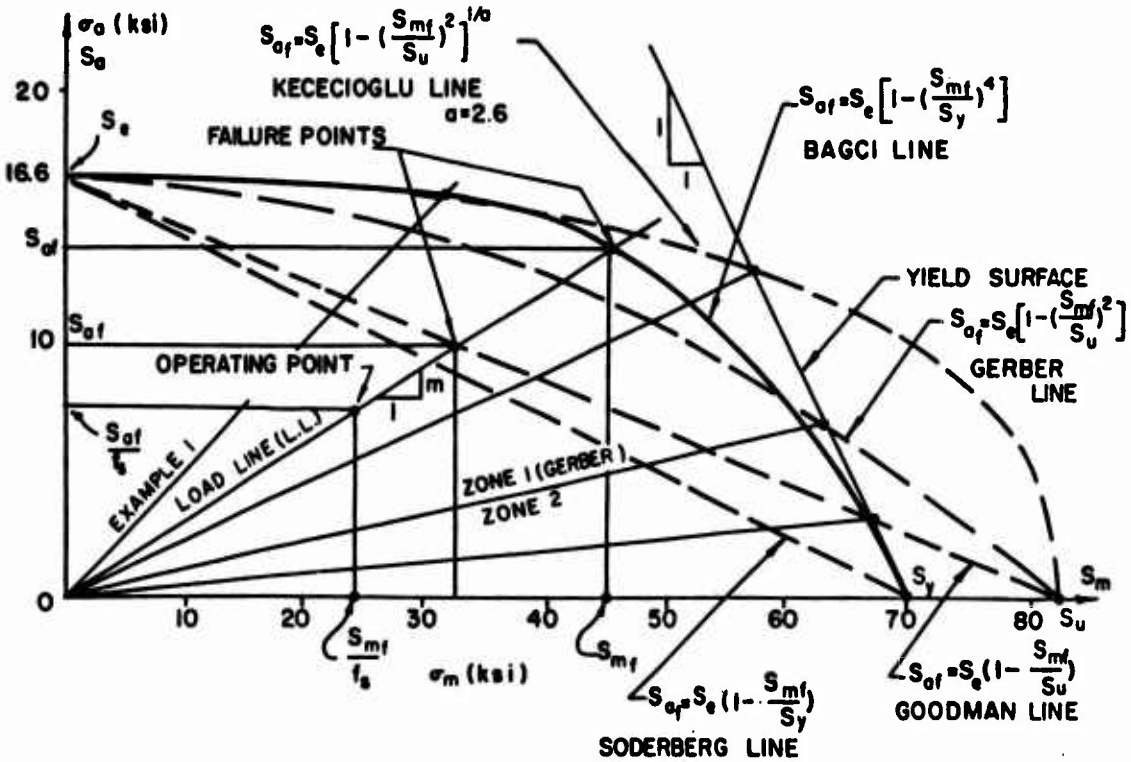

Figure 1. Mean Stress Diagrams at a Specific Value of N [16]

$S_{mf} = S_{af}/m$ is substituted in equation (7); m is the slope of the load line:

$$S_{a_f}^4 + \frac{(m\,S_y)^4}{S_e}\,S_{a_f} - (m\,S_y)^4 = 0 \qquad (7a)$$

Equation (7a) has only one valid root

$$S_{a_f} = (E_1 - \sqrt{Y})/2$$

where

$$E_1 = \sqrt{\frac{2\,C_1}{\sqrt{Y}} - Y}\,, \quad Y = A_1 + B_1$$

$$C_1 = \frac{(m\,S_y)^4}{S_e}$$

$$A_1 = \left[\frac{C_1^2}{2} + \sqrt{\frac{C_1^4}{4} + \frac{Q^3}{27}}\,\right]^{1/3}$$

$$B_1 = \left[\frac{C_1^2}{2} - \sqrt{\frac{C_1^4}{4} + \frac{Q^3}{27}}\,\right]^{1/3}$$

$$Q = 4\,(m\,S_y)^4$$

Equation (7) appears to be a reliable unified equation that can be used to analyze machine elements for fatigue life and synthesize them for specified fatigue life with specified reliability and factor of safety. It is also easy to use in computer-aided fatigue design of complex machine elements [15, 16].

THE S-N DIAGRAM

For high cycle fatigue and $N \geq 10^3$ for carbon steels it has been customary to use $S'_e = 0.5\,S_u$ for $N \geq 10^6$, $S'_e = 0.9\,S_u$ for $N = 10^3$, and straight line distribution on the log-log scale for $10^3 \leq N \leq 10^6$ as given by

$$\log S'_e = -A \log N + B, \quad 10^3 \leq N \leq 10^6 \qquad (8)$$

where

$$A = \frac{1}{3}\log\,(0.9\,S_u/S'_{e_\infty})$$

$$B = \log\,[(0.9\,S_u)^2/S'_{e_\infty}]$$

and

$$S'_{e_\infty} = h\,S_u$$

is the endurance limit for $N \geq 10^6$, and h = 0.5 for carbon steels.

Any of equations (1), (2), (4), (6), and (7) combined with equation (8) form the fatigue failure surface shown for equations (2) and (7) in Figure 2. The point at which the load line pierces this failure surface at given N defines S_{af} and S_{mf} for that N and the load line slope m.

Extensive research has been done on the validity of equation (8) and the reduced value of S'_e due to the notch [5, 13, 14, 17-20]. It represents the experimental data very well. In fact, the value of h is 0.5 for carbon steels as illustrated by experimental data [5, 14, 17]. The value of h varies for other materials and S'_e cannot be clearly defined at $N = 10^6$; for example, the endurance limit for aluminum alloys can be approximated at $N = 5 \times 10^8$ with $h \cong 0.37$ for wrought forms and with $h \cong 0.31$ for casting [20-23]. Determination of h for different materials with different properties, including composite materials, will require extensive experimental data and is a needed research activity [24, 25].

It has been observed in the literature on fatigue design of machine elements that $(C_f\,S'_e)$ is used in place of S'_e in equation (8). This approach assumes that C_f has no effect on the fatigue strength at $N = 10^3$. This assumption is a serious engineering error and should not be practiced. The effect of C_f on the fatigue strength at $N \leq 10^3$ is shown by the experimental data on the S-N curves given in Figure 3; fatigue strength reduction is due only to the notch.

An equation for S'_e has been formulated to include on the S-N diagram the low cycle fatigue zone for $N \leq 10^3$ [17]. The equation makes use of the strain hardening exponent in the true stress-true strain equation for plastic behavior, fraction reduction in the area, strain offset, and true strain at fracture in static tensile test. Equation (8) is valid for $N \geq 10^3$ [17]. The proposed relationship for S'_e [17] is difficult to use for fatigue design of machine elements due to the lack of required data; but the relationship illustrates that the S-N diagram

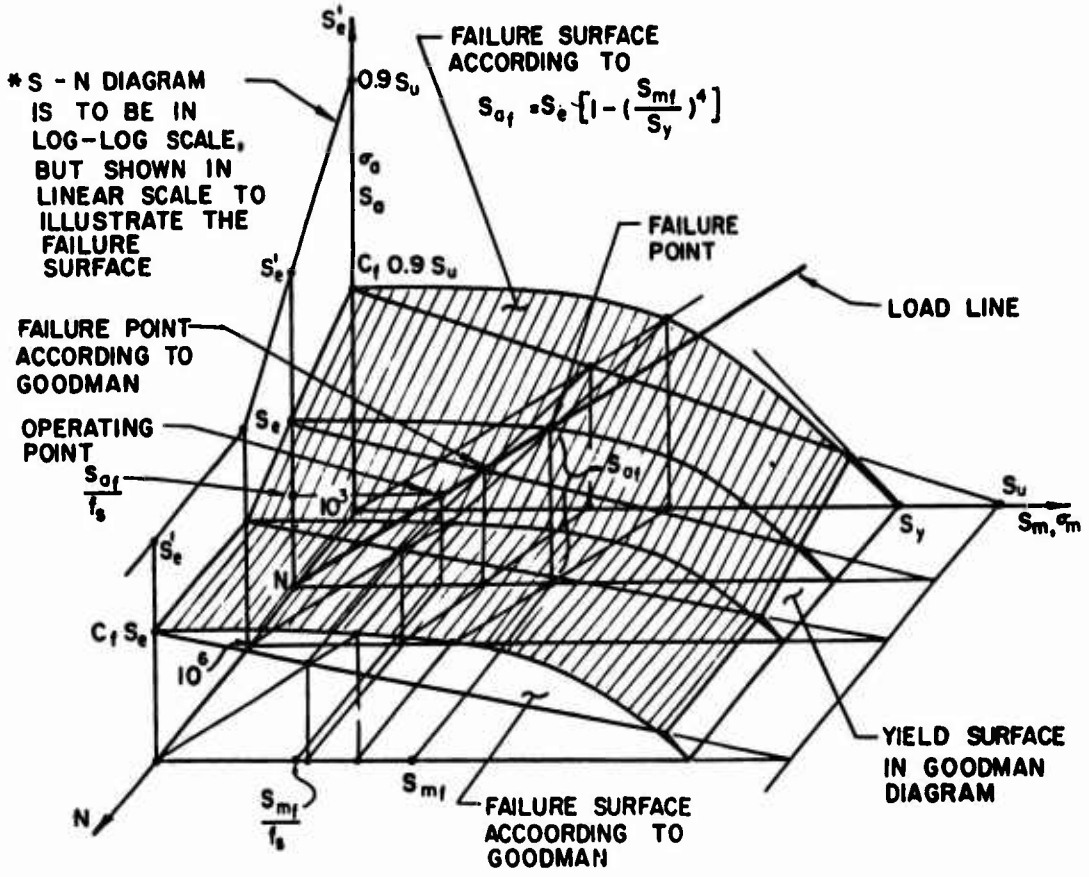

Figure 2. Fatigue Failure Surface Depicting the Relationship between the S-N Diagram and the Mean Stress Diagrams [15, 16]

for $N \leq 10^3$ can be completed by connecting S_U at $N = 1$ to $0.9\,S_U$ at $N = 10^3$ by a straight line on the log-log scale for carbon steels, for 50% reliability.

FATIGUE STRENGTH REDUCTION FACTOR, C_f

Many complex factors contribute to C_f. At present experimental research is needed to define the values of factors contributing to C_f. Major components of C_f are due to notch, surface finish, and size and level of reliability (survival rate). Temperature, environment, cumulative damage, and shock loading factors can also contribute to C_f depending on the operating conditions of the machine element. C_f can be written as

$$C_f = c_n\, c_s\, c_z\, c_r\, c_t\, c_e \qquad (9)$$

where c_s is the surface finish factor [5]; c_z is the size, shape, and rolling direction factor [5, 15]. The reliability factor c_r depends on the desired level of failure rate; it is a statistical quantity on which a sizable literature exists [12-14, 28-32]. The temperature factor c_t is used to consider fatigue strength reduction at high temperatures and fatigue strength increase at subzero temperatures for certain metals. Determining c_t is difficult because of a lack of data. Experimental research is needed [33-35].

The fatigue strength for carbon steel decreases as temperature increases. Thus for AISI 4340 steel

$$c_t = 1 - 0.5\left(\frac{T - 70}{930}\right)^n \qquad (10)$$

for $70°F \leq T \leq 1000°F$; $n = 3.5$; $c_t = 1$ for $T \leq 70°F$. In equation (10) $n = 1.3$ for titanium alloys. For

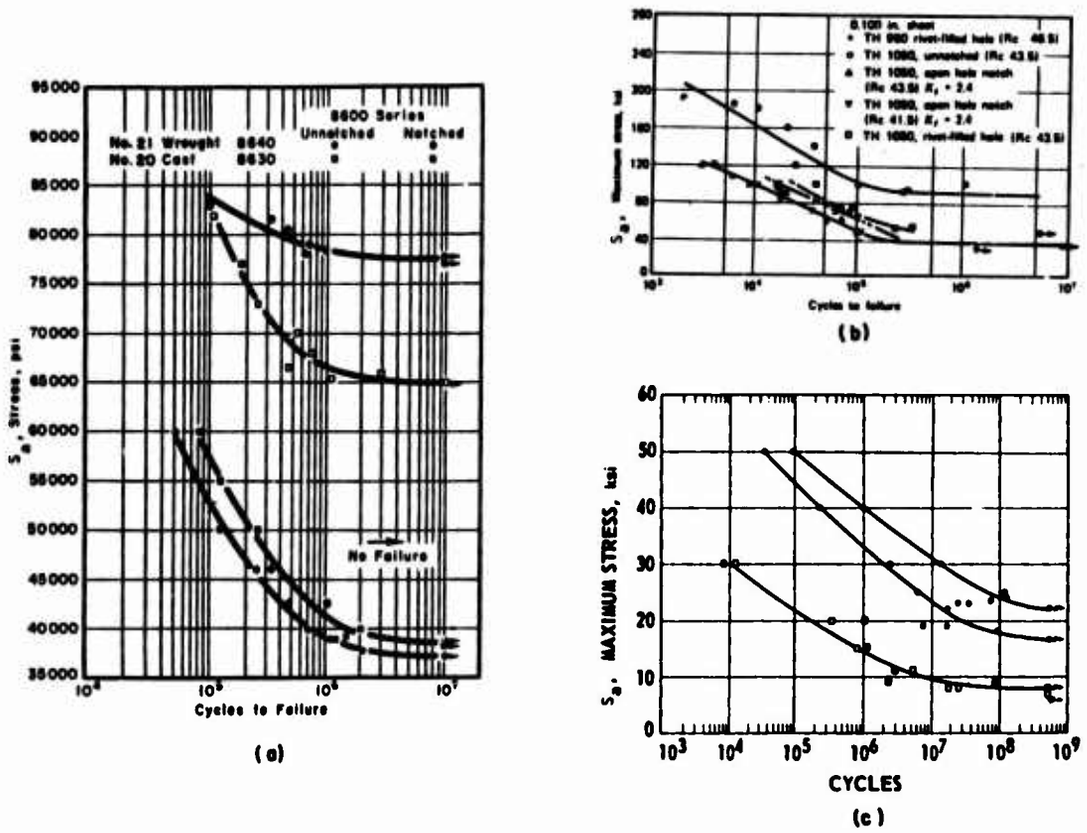

Figure 3. Experimental Data for S-N Diagrams
(a) Cast 8630 and wrought 8640 steels hardened and tempered to the same strength level [5]
(b) 17-7PH stainless steel sheet [26]
(c) 2024-T4 aluminum alloy, recrystallized: smooth ○, notched □, not recrystallized: smooth ●, notched ■, [27]

AISI 2024 steel equation (10) becomes

$$c_t = 1 - 0.5\left(\frac{T - 70}{430}\right)^n \qquad (11)$$

for 70°F ≤ T ≤ 500°F, where n = 1.5; c_t = 1 for T ≤ 70°F. Mild steel presents a complex pattern for c_t. Thus, it is determined for -350°F ≤ T ≤ 1000°F as

$$c_t = 1.0472 - 0.3075 \times 10^{-7}\left(\frac{T^3}{3} - 360T^2 + 45500T\right) \qquad (12)$$

which predicts c_t = 1 at T = 70°F, c_t = 1.2824 at 900°F, c_t = 2 at T = 650°F, and c_t = 2.74 at T = -300°F.

The environmental effect factor c_e considers the the effect of shock loading [15], corrosive conditions affecting surface conditions, random loading, and cumulative damage effects. Again, experimental data are needed on c_e for design decision making. Any of these fatigue strength reduction factors is considered 1 if proper data are not available; unfavorable conditions are controlled by introducing a greater margin of safety for the design value of (S_{af}/f_s) where f_s is safety factor.

$c_n = 1/k_f$ is the notch factor and

$k_f = 1 + q\,(K_t - 1)$

In these expressions q is the notch sensitivity, and K_t is the combined theoretical geometric stress concentration factor. Neuber [36] offered the stress concentration gradient method to determine K_t. The method has been used [28] to develop K_t for steel shafts with semicircular grooves. The complexity of obtaining K_t using Neuber's approach encouraged others to seek simpler ways for determining K_t. The following form has been proposed for K_t [37].

$$K_t = 1 + q_b(k_b - 1) + 0.866\, C\, q_s(k_s - 1)\frac{\tau}{\sigma_b} \qquad (13)$$

Equation (13) is for planar state of stress as in shafts; σ_b is the bending stress, τ is the shearing stress, and q_b and q_s are the notch sensitivities for normal and shearing stresses respectively. $C = c_s\, c_z\, c_r\, c_t\, c_e$. The geometric stress concentration factors for bending and torsional stresses are k_b and k_s. Equation (13) does not appear to be reliable because K_t is dependent on C and stress ratio. For example, for C = 1, $q_b = q_s = 1$, $k_b = k_s = 2$, and $\tau/\sigma_b = 1$; K_t must be 2, but equation (13) predicts a K_t value of 2.866. If $\tau/\sigma_b = 2$, $K_t = 3.73$ instead of 2.

Bagci [15, 16] suggested that K_t can be computed from the basic stress of the strength theory used in the design equation that relates S_{af}/f_s to the basic stress σ'_a experienced by the machine element. Thus,

$$K_t = \frac{\sigma'_c}{\sigma'_o} \qquad (14)$$

where σ'_o and σ'_c are the basic stresses defined using the maximum values of the normal and shearing stress components but σ'_c includes the stress concentration factors and notch sensitivity ratios for bending, axial loading, and torsional loading. For example, a point on a shaft is subjected to bending stress σ_b, axial stress σ_x, and torsional stress τ. Use the distortion energy theory to obtain

$$\sigma'_o = \sqrt{[(\sigma_{b_a} + \sigma_{b_m}) + (\sigma_{x_a} + \sigma_{x_m})]^2 + 3(\tau_a + \tau_m)^2} \qquad (15)$$

and

$$\sigma'_c = \sqrt{\left[(\sigma_{b_a} + \sigma_{b_m})k_b + \frac{q_b}{q_x}(\sigma_{x_a} + \sigma_{x_m})k_x\right]^2 + 3\left((\tau_a + \tau_m)\frac{q_s}{q_b}k_s\right)^2} \qquad (16)$$

The subscripts a and m designate alternating and mean components of stresses respectively; k_x is the geometric stress concentration factor for axial loading, and q_x is the corresponding notch sensitivity at the point of concern. Useful data on q_b, q_x, and q_s are limited, especially for q_x and q_s. The quantity q_x is very close to q_b and is considered to have the same value. The limited data available show that q_s differs from q_b by a small amount; thus, if data are not available, $q_s = q_b$ can be used [5, 20, 36, 38]. Determining q values for different materials under different loading conditions is a needed research activity.

Equations (14) - (16) have been used to determine K_t in tests of notched specimens [28, 39]; $\sigma_{x_a} = \sigma_{x_m} = 0$, and $q_b = q_s$. The values determined for K_t were the same as those given in plots of K_t and in tables [28, 39]. Computing K_t by equation (14) therefore is the most reliable method at present.

DESIGN EQUATION

A design equation used to synthesize a machine element for fatigue life or to determine its fatigue life is

$$\frac{S_{a_f}}{f_s} = \sigma'_a \qquad (17)$$

where σ'_a is the alternating basic stress the element experiences and is defined by the strength theory used. $S_{mf}/f_s = \sigma'_m$ can also be used; σ'_m is the mean basic stress experienced by the machine element. The unknown in equation (17) is defined and solved. It could be the dimension, the safety factor, or the number of stress cycles. Basic stress forms for different strength theories for two- and three-dimensional states of stress have been given [15]. The forms include distortion energy theory, maximum shearing stress theory, total strain energy theory, and Coulomb-Mohr theory that considers the ratio of compressive strength to tensile strength of a material. Computer-aided design examples are available [15], as are additional design applications, including fatigue design of cantilevered welded joints [16].

COMMENTARY

Reliable design of machine elements for a desired level of fatigue life depends on reliable data that can be used to determine the components of the fatigue

strength reduction factor C_f. At present insufficient data are available to allow reliable decision making for the values of surface finish, size, shape, and temperature correction factors in C_f. Similarly insufficient data are available on the notch sensitivities q_b, q_x, and q_s. Geometric stress concentration factors for stress raisers with complex geometries and complex connections are urgently needed for proper utilization of fatigue theories. These data are needed to simplify fatigue design activities, to allow rapid and reliable computer-aided designs at low cost, and to improve productivity. With such data, fatigue design of structures, machine and mechanism components, shafts, crankshafts, welded joints, and contacting elements could be simplified and made more reliable.

Fatigue design of contacting elements, welded components, bolted connections and bolts, springs, and crankshafts as well as utilization of finite element in fatigue design of machine members and cumulative damage and fatigue design for random loading will be subjects of future review articles.

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LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains articles about high temperature damping of dynamic systems and aseismic base isolation.

Dr. D.I.G. Jones of Air Force Wright Aeronautical Laboratories, Wright-Patterson Air Force Base, Ohio has written an article describing progress in three major areas of high temperature vibration control technology since 1979, namely: development of high temperature polymeric and vitreous enamel damping materials, and measurement and characterization of the damping behavior of these materials; practical design and application of damping treatments in industry and commerce; and frictional damping at interfaces.

Mr. James M. Kelly of the Department of Civil Engineering, University of California, Berkeley, California has written a paper which describes the development of base isolation, experimentation on the concept, and the application of the concept to several recently completed structures.

HIGH TEMPERATURE DAMPING OF DYNAMIC SYSTEMS

D.I.G. Jones*

Abstract. This article describes progress in three major areas of high temperature vibration control technology since 1979, namely:

- *development of high temperature polymeric and vitreous enamel damping materials, and measurement and characterization of the damping behavior of these materials*
- *practical design and application of damping treatments in industry and commerce*
- *frictional damping at interfaces*

Since the second review of high temperature damping in 1979 [1], a number of new investigations have addressed some of the problems identified in that article. Some of these investigations are not yet complete and have not been fully reported, but significant progress has been made.

HIGH TEMPERATURE MATERIALS

Two recent reports have catalogued measured complex modulus data for several enamel compositions [2-3]. One current study has to do with developing jet engine-compatible enamels for damping applications [4]; another study is concerned with identifying and tailoring polymeric compositions for damping application at high temperatures [5]. However, it will be some time before the final results of these investigations can be reported.

Progress has also been made in the techniques of analytically modeling complex modulus properties in both the time and frequency domains; complex modulus data are measured as a function of reduced frequency [6]. With this information, prediction of either transient or steady-state harmonic response of systems incorporating these materials will be possible. Such prediction is timely now that the old question of the applicability of complex modulus material damping data to transient oscillations has been laid to rest; it has been shown that non-causal response does not occur if the measured variations with frequency of stiffness and loss factor are properly taken into account [7].

Standardization activities include the completion of a draft ASME standard for measurement of damping material properties by the resonant beam technique [8], continuing progress toward an ANSI standard on characterization of complex modulus properties [9], and initiation of a round robin series of tests to evaluate these standards in engineering practice [10]. Several material suppliers are now providing potential users with complex modulus data in nomogram form [11, 12]. It is hoped that others will follow suit, so that designers will have better information on which to base their decisions.

DESIGN AND APPLICATIONS

A program [13] to create a design guide for damping application is in progress; the final report should be especially helpful to designers in the aerospace industries. Applications of damping technology are continuing in the diesel engine industry [14, 15] and elsewhere, but most applications have not been reported in the open literature.

The successful program to implement a layered damping treatment on the inlet guide vanes of the TF-30 engine [16] has led to efforts to develop elastomeric tooling methods. These methods will replace the autoclave/vacuum bag approach currently being used [17]. Efforts have also been made to develop lower cost treatments [18].

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Attention has been given [19, 20] to the development of efficient finite element software for predicting damping treatments and modifications of structural response. Several short courses and seminars, listed in the **DIGEST**, will be offered to provide information about available technology. This transition process should accelerate in the next several years [21].

New programs to develop and evaluate the impact of damped, shroudless, fan blades on engine design and performance are currently being initiated [22, 23] and should lead to potentially useful concepts for future applications. A recently completed program [24] has demonstrated the feasibility of enamel coatings for introducing significant levels of damping in turbine blades at high temperatures. Enamel coatings in the dovetail and on the airfoil were considered.

FRICTIONAL DAMPING AT INTERFACES

Frictional damping continues to be the mainstay for control of undesired vibration in jet engine turbine blade-disk configurations but reports of such application are rarely made in the open literature. Theoretical investigations of many of the phenomena expected to arise in frictionally damped blade-disk systems have been reported [25-30].

CONCLUSIONS

Progress continues to be made in the direction of finding materials to control resonant vibrations at high temperatures. It is expected that, as these materials become more widely available and known, efforts will be made to utilize them in specific problem areas. As integrally manufactured components -- including integral blade-disk systems and single crystal and directionally solidified blades -- come into more common use, high temperature damping materials will probably be used in areas where component vibrations occur and under conditions in which it is difficult to move resonant frequencies into noncritical areas. In some cases frictional damping mechanisms might have to be designed for use in these new component systems.

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ASEISMIC BASE ISOLATION

J.M. Kelly*

Abstract. The concept of base isolation is based on accepted physical principles. It has not, however, been readily accepted by the structural engineering profession, perhaps because the concept runs counter to conventional methods of aseismic design. A base-isolated structure is decoupled from the damaging horizontal components of earthquake ground motion by a mechanism that prevents or reduces the transmission of horizontal acceleration into the structure. Although many base isolation schemes have been proposed during the last century, virtually all remained unimplemented until the concept became a practical reality with the recent development of multilayered elastomeric bearings. This development began with the design of bearings for bridges and bearings used to isolate structures from ground-borne acoustic vibration. This paper describes the development of base isolation, experimentation on the concept, and the application of the concept to several recently completed structures.

Aseismic base isolation, a relatively old concept that has only recently become a practical possibility through developments in rubber technology, is an approach to earthquake protection in complete contrast to standard aseismic design. Conventional methods seek to protect buildings against earthquake attack by increasing the strength of structures and their capacity to dissipate energy. Seismic regulations require that the earthquake attack be absorbed by inelastic action of the structural system; consequently the structure, particularly at beam-column connections, must be designed with the requisite ductility. Inelastic behavior has the effect of reducing the natural period of the structure and increasing the damping, both of which act to limit the response of the building. However, inelastic behavior inevitably involves damage to the structural system and to nonstructural components and equipment.

The horizontal components of earthquake ground motion, amplified by the dynamic response of the structure, are the most damaging to a building and its contents. In the base isolation approach, the building floats on a system of foundation bearings that act to uncouple the building from horizontal ground accelerations. The building is isolated at the base from the damaging components of the earthquake. Not only is the structural system protected but occupants and contents are protected as well.

The development of elastomeric multilaminate bearings for bridges and of acoustic isolation bearings for buildings has led to the application of aseismic base isolation. Several base-isolated buildings have now been constructed. Buildings up to about 15 stories in height can be base isolated. Buildings of greater height have long natural periods and must be designed with lateral stiffness and strength to resist wind loads. Base isolation is also an attractive alternative for special structures that are very stiff -- for example, power plants -- and for structures in which expensive or essential equipment is housed, such as telephone exchanges, hospitals, and pumping plants.

EARLY BASE ISOLATION SCHEMES

A very early base isolation system was proposed and patented by a medical doctor named Calantarients in England in 1909 [1]. Calantarients separated the structure from the foundation by a layer of talc. He understood that the isolation system reduced accelerations in the isolated building at the expense of large relative displacements between the building and the foundation. He designed utilities connections -- in those days gas lines and sewage pipes -- to accommodate these displacements. In fact, his system incorporated all the elements now considered

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necessary for a base isolation system: a method of decoupling the building from the foundation, a method whereby utility lines can withstand large relative displacements, and a wind restraint system.

In his design for the Imperial Hotel in Tokyo, which was completed in 1921, Frank Lloyd Wright used the concept of base isolation. His design was in complete contrast to accepted practice and was a subject of great controversy. A layer of eight feet of fairly good soil and a substratum of soft mud underlay the site of the hotel. Wright thought of the mud as isolating the building from earthquake action. The layer of soft mud below the upper layer of eight feet of surface soil was to Wright [2] "a good cushion to relieve the terrible shocks. Why not float the building on it?" He integrated the soil layer and the building with a set of closely-spaced short piles that penetrated only the soil stratum. The piles and the building were intended to float on the mud substratum. The Imperial Hotel was one of the few western-style buildings to survive the devastating Tokyo earthquake of 1923. Economics and the effects of air pollution on the soft stone used for the building brought about its demolition in the 1960s.

The flexible first story concept was another early approach to structural isolation. The lateral stiffness of the columns of the first story was designed to be much lower than that of columns on upper levels. Deformations under earthquake loading would be restricted to these first story columns. This concept was first proposed by Martel in 1929 [3] and was further studied by Green in 1935 [4] and Jacobsen in 1938 [5]. Because the columns had to be very flexible, the interaction of the vertical load and the large lateral displacements that would necessarily develop if accelerations were reduced would lead to structural instability.

In the above papers the first story columns were assumed to behave elastically, and no damping was included. In a later modification of this approach, known as the soft first story method, Fintel and Khan [6] proposed that first story columns be designed to yield during an earthquake, thus limiting the shear forces transmitted to the rest of the structure. At the same time, the hysteretic action of the yielding columns would provide an energy-absorbing mechanism, and displacements would be reduced. The concept was shown to be impractical in a computer study [7]: the post-yield stiffness of the columns would have to be impractically small if shear forces in the upper stories were to be reduced. As a consequence, the necessary lateral displacements would still be large. The effect of the vertical load on yielded columns could render the system impractical. A more recent paper [8] resurrects the soft first story concept in a proposed structural design scheme involving a double basement and special construction over three lower floors.

MODERN ISOLATION SCHEMES

The ultimate in isolation would be to place an entire structure on roller bearings, in which case, in principle, no horizontal force would be transmitted into the structure. Wind load and the fact that the system would have no restoring force make the roller bearing system impractical.

A modification of the approach has been suggested by Matsushita and Izumi [9], who proposed that such rollers be shaped so that the building would rise when laterally displaced. The increase in potential energy would provide the restoring forces. The results of some testing of this approach have been reported [8]. The system is inherently free of damping; this is felt to be a disadvantage. An analogous study of various isolation schemes [10] has clearly demonstrated that some damping is needed in isolation systems.

A conceptual study of such a system was published in 1970 by Caspe [11]. In his system the weight of the building is carried on ball bearings. A neoprene pad provides a restoring and recentering force; control rods act as wind restraints and dissipate energy under large seismic displacement. Numerical studies of response during typical earthquakes indicated that the system might be effective, but it has not been implemented.

Many other system have been described, although in less detail. Some of these systems have been reviewed by Williams [12]. In one analytical study [13] random vibration theory was used to predict the response of a system proposed by Williams in his review. The results indicated that the system is exactly that of Calantarients.

Other systems proposed in Japan involve both active isolation and extensions of the roller bearing concept [14-17]. Isolation of nuclear power plants by flotation has been proposed [18] for earthquake protection and for other reasons.

Steel helical springs with viscous dampers have also been proposed [19] as isolation elements. In a system using helical springs the vertical stiffness of the isolation system will be approximately double the horizontal stiffness; the building will therefore be subject to large rocking motions in addition to horizontal displacements. These motions could exacerbate the problems associated with connections of utilities and would in many cases be unacceptable.

IMPLEMENTED BASE ISOLATION SCHEMES

The development of multilayer elastomeric bearings has made the concept of base isolation practicable. Many years of experience with bridge bearings [20, 21] have shown that rubber is a reliable and predictable engineering material. High-precision elastomeric bearings with many very thin layers are now used in helicopters to replace journal bearings in locations where motion is cyclic rather than rotary [22]. A different form of multilayer elastomeric bearing is used for fenders on docks and wharves [23]. Recognition of the engineering qualities of rubber has led to the use of elastomeric bearings in several buildings that have been built or are under construction on base isolation systems.

Heinrich Pestalozzi School, Skopje, Yugoslavia. This school, completed in 1969, is apparently the first building in which a base isolation system was incorporated [24]. The building was designed by a Swiss architect; the engineering design was done by a Swiss civil engineer. The Swiss group of the Interparliamentary Union donated funds for construction of the school during a rebuilding effort following the earthquake of 1963. The rubber bearings differ from those proposed in research on base isolation at the Earthquake Engineering Research Center of the University of California, Berkeley, in that they do not contain reinforcing steel plates and are fabricated by gluing together several layers of rubber. The vertical stiffness of such bearings is therefore not much greater than the horizontal stiffness.

High-Rise Office Building, Athens, Greece. A high-rise office building designed by A.S. Ikonomou was constructed on a base isolation system in Athens, Greece, in 1972 [25]. The system apparently uses conventional bridge bearings as isolating elements and incorporates mechanical fuses as wind restraints. A system based on the principles used in the design of this high-rise building will be used in the construction of a three-story concrete prototype dwelling. The behavior of the proposed structure has been studied analytically; its response to several earthquake records both when equipped with the Alexisismon system and conventionally founded has been evaluated [26].

Kroeberg Nuclear Plant, South Africa. This nuclear plant, which was designed and built by French engineers, uses a base isolation system designed by Electricite de France (EDF). Of the systems described here, the EDF is the most expensive -- several thousand dollars per bearing -- and the most highly developed. It was specifically designed for nuclear power plants and allows a standard power plant design for any site condition, including areas of high seismicity [27-30]. The power plant rests on a double raft foundation; isolation bearings are interposed between the upper and lower rafts.

The bearings in the EDF system consist of steel-reinforced elastomeric pads and a pair of friction plates, one of stainless steel and the other of a leaded bronze alloy. The purpose of the slipping plates is to limit the horizontal acceleration of the structure above the isolation system. The stainless steel/leaded bronze combination provides a friction factor of approximately 0.20. The leaded bronze plate is vulcanized to the upper part of the elastomeric pad; lead particles are distributed throughout the bronze to lubricate the contact between the two plates. The stainless steel plate is anchored in an intermediate concrete supporting structure. The Kroeberg Plant is in an advanced stage of construction; other French power plants in the Rhone Valley in which base isolation will be used have been started or are planned.

The expense of the individual bearings used in this system is justified: the cost of the power plant and its components is greatly reduced because a standardized design can be used. Such bearings would be too costly for non-nuclear applications.

New Zealand Government Building, Wellington, New Zealand. Considerable work on the development of rubber bearings as isolators has been carried out at the Physics and Engineering Laboratory of the New Zealand Government Department of Scientific and Industrial Research in cooperation with the Government Ministry of Works and the universities. Several systems have been described for buildings [31, 32], and one specific design for a nuclear power plant has been proposed [33]. A particular design has been selected and tested for a proposed government building, a four-story reinforced concrete frame structure [34] to be located in Wellington, a region of high seismicity.

The base isolation system involves natural rubber bridge bearings in which a cylindrical hole has been drilled and into which a lead plug has been inserted. The lead plug deforms in shear with the bearings and provides damping to the system [35, 36]. Because the maximum bearing displacement for several artificial design earthquakes was estimated to be 150 mm, a gap that wide must be left between the basement slab and the periphery of the building. This gap will be covered by a sliding grill.

At the second floor level the entrance steps are designed to bridge the gap. Special service connections between the exterior and the interior have been designed to accommodate the 150 mm horizontal motion. The cost of the bearings and their installation, including additional foundation work, has been estimated at 3.5% of building cost. The cost of each bearing appears to be about two thousand dollars.

Elementary School, Lambesc, Marseilles, France. This school was built on a base isolation system called the GAPEC system. The system [37, 38] was developed at the Centre National de la Recherche Scientifique in Marseilles and uses bearings of a multilayer construction in which natural rubber sheets and steel plates have been bonded by vulcanization. The main characteristic of the bearing is that the vertical stiffness is very much higher than the horizontal stiffness.

The school, located in the town of Lambesc near Marseilles, was built on 152 such isolators; it is approximately 254 ft by 100 ft, is comprised of three stories, and includes three buildings, each separated from the other by 100 mm. Isolators 1 ft in diameter and with a rubber thickness of 2 in. were used in the construction of the buildings. The school was designed for an VIII M.M. earthquake.

The school building was constructed of prefabricated concrete panels that without isolators would not have satisfied seismic requirements unless the thickness of the concrete and the cross section of the reinforcement had been increased significantly. Such changes would have substantially increased construction costs. It has also been reported by Delfosse that three buildings are under construction on the GAPEC system in Saint-Martin de Castillon.

EXPERIMENTAL RESEARCH ON BASE ISOLATION

Elastomeric Bearings. Multilayer elastomeric bearings have made possible the century-old concept of base isolation. Natural rubber bearings have been used in the United Kingdom to isolate buildings from subway rumble [39]. These bearings were a logical development from bridge bearings, and the concept ultimately was extended to the protection of structures against seismic loading.

A testing program designed to verify the approach -- sponsored by the Malaysian Rubber Producers' Research Association of the United Kingdom and the National Science Foundation -- was carried out on the shaking table at the Earthquake Engineering Research Center (E.E.R.C.) of the University of California, a facility developed for large-scale seismic testing. The 20-foot square shaking table can test model structures up to 100,000 lbs total weight and can simulate historical earthquake ground motion records or artificial records at very high accelerations.

Several designs of rubber bearing have been tested. A one-third scale, 40-ton structural model was mounted on four natural rubber bearings that were manufactured by conventional molding techniques by a commercial rubber company. The maximum acceleration experienced by the structure on the bearings was less than one-tenth that experienced by the same model on a conventional foundation [40]. Accelerations experienced by internal equipment can be reduced by an even greater amount [41].

Wind Restraints. The low transverse stiffness of isolation bearings permits a low-frequency motion that can be uncomfortable for occupants and cause fatigue in utility connections. Some form of wind restraint is therefore needed. One type of wind restraint -- developed at the University of California, Berkeley, and tested on the shaking table of the E.E.R.C. [42] - prevents lateral movement of an isolated structure under small horizontal load but breaks at a specified force. The structure then moves freely on the rubber bearings.

The mechanical fuse is a small steel pin with a notch machined around its circumference. The pin is loaded in shear at the notch and will break suddenly at a reasonably well-defined shear load. When tested, the pin functioned effectively; it broke rapidly and underwent little plastic deformation. The dynamic breaking force could be predicted reliably from the results of static tests performed on the pins.

Energy-Absorbing Devices. No base isolation system can isolate a building from all earthquake frequencies. With motions as random as those of an earthquake, there will always be some component of the input that will be in resonance with the system. The effects of this resonance can be avoided by providing a degree of damping in the isolation system. Although rubber bearings provide a certain amount of damping, at best equal to approximately 10% equivalent viscous damping in the lowest mode, higher damping may be necessary to reduce displacements. It can be provided by including energy-absorbing devices in a base isolation system. The combination of such devices and rubber bearings provides an isolation system with a number of attractive features.

Several energy-absorbing devices highly resistant to cyclic fatigue have been tested in conjunction with natural rubber bearings. The mechanism of energy absorption is the cyclic plastic deformation of hot-rolled low carbon mild steel [43-45].

These devices play two roles [46] in the response of the system to earthquake loading. Because they are elastic for small displacements and their elastic stiffness is high relative to that of the rubber bearings, the devices act as mechanical fuses and cause the model structure to behave for small excitations as if rigidly fixed. Thus, under small excitations the structure typically amplifies the ground acceleration. As the excitation grows more intense, the device yields, and large hysteretic loops are produced as the structure oscillates. The tangent stiffness of the device when yielded is around 5% of its elastic stiffness. Thus, the fundamental frequency of the structure drops, and the system acts as an isolator with very high damping. The accelerations induced in the structure are of course somewhat greater than if rubber bearings alone were used, but the displacements at the bearings are reduced.

Frictional Dissipation of Energy. Sliding friction is an attractive mechanism for the absorption of energy because, in contrast to other energy-absorbing devices, it operates in any direction without need of mechanical connection. Experiments using friction to dissipate energy and control displacements have been carried out on the shaking table [47]. The frictional element in this system also doubled as a fail-safe device in the sense that, if the rubber bearings for some reason failed, the structure would be carried on the sliding surfaces.

The system under test did function as anticipated: high damping was introduced, and the displacements were reduced as compared to those when rubber bearings were used alone. Also, the friction device operated as a fail-safe system when the earthquake input was increased to a level that caused the bearings to fail.

However, the sudden change in direction of the frictional force when the relative velocity between structure and foundation changed sign produced a high-frequency acceleration in simulated equipment in the model. This could be a hazard in buildings with sensitive equipment.

An isolation system that would reduce this hazard while combining the best features of frictional control -- namely simplicity and multidirectionality -- with fail-safe action and the centering action of the rubber bearings would be one in which roughly half the weight of the building were carried on rubber and half on teflon-stainless steel sliding bearings. The isolation frequency would be reduced from that for bearings alone; the effective viscous damping factor in the isolated mode would be increased. With this combination, the building would experience very low accelerations with controlled displacements, and the high-frequency energy transmitted to the equipment would be reduced.

Lead-Rubber Bearings. The isolation system using bearings having a central lead plug that was developed in New Zealand and is now installed in a building there has also been experimentally studied on the shaking table at the E.E.R.C. using the same model. The results [48] are very positive in that accelerations produced in the model were lower than peak ground accelerations, and displacements were controlled. The lead plug acts as a wind fuse and as an energy absorber. It has the advantage of being multidirectional, and the lead seems immune to low-cycle fatigue. A possible disadvantage is that the lead plug shifts the isolated natural frequency of the system above that for the rubber alone; this shift tends to move the system into the more energetic range of the earthquake spectrum.

CONCLUSIONS

The design of practicable base isolation systems for many types of structure is now possible. Very simple systems will be used to isolate relatively small buildings with limited occupancy -- such as transformer buildings or pump stations. Somewhat more elaborate systems will be designed for such buildings as hospitals and schools; similar public buildings that must be designed for severe earthquake loading. Because buildings must now be designed by dynamic analysis, the design costs will be less when base isolation is used.

More elaborate and costly systems are appropriate for nuclear power plants if any more such plants are built. The seismic qualification of equipment has always been of concern in the design of critical components in nuclear power plants, but the design of equipment for seismic loading has become important in non-nuclear installations as well. The cost of internal equipment in, for example, a telephone exchange is potentially several times the cost of the building in which it is housed. The most compelling argument for base isolation may thus be the protection afforded internal equipment and piping.

Although the main structure of a building or power plant can be protected from the damaging effects of an earthquake with relative ease, the necessary strengthening of the main structure increases the seismic loads transmitted to nonstructural components and equipment. The response of nonstructural components has been shown to be determined primarily by the response of the primary structure to earthquake ground motion and not by the ground motion itself.

The design process for components to be housed in conventionally founded structures is particularly difficult. The process is complicated both by uncertainties in the specification of ground motion and by uncertainties about the properties of the primary structure. Such uncertainties can be avoided and safer design realized by the alternative approach of constructing buildings on base isolation systems such as those described above.

The major benefits of base isolation to equipment and piping design are that considerations of equipment-structure interaction and inelastic response are unnecessary. In addition, because the primary structure above the isolation system moves as a rigid body, the displacement time histories of all support points of a piping system will be identical. Thus, multiple support response analysis, with its controversial aspects, need not be employed. Clearly, this is of primary importance in the aseismic design of equipment and piping installations.

Although base isolation has generally been proposed for new construction, the concept could readily be adapted to the rehabilitation of older buildings of architectural and historical merit that presently do not comply with code requirements. There are many such buildings, and owners must choose between expensive and disruptive rehabilitation or demolition. The technology to jack up a building and insert rubber bearings exists. It is anticipated that rehabilitation by base isolation will be a much less costly and disruptive procedure than the current practice of gutting the interior and adding new walls, but the question of relative cost remains to be answered.

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BOOK REVIEWS

MECHANICS TODAY, VOLUME 4

S. Nemat-Nasser, Editor
Pergamon Press, Inc., Elmsford, NY
1978, 569 pages, $68.00

This book follows the tradition established by previous volumes in this series and introduces the reader to the current work of some of the most active researchers in the fields of solid mechanics and applied mathematics. The present volume consists of six fairly long articles in the areas of applied mechanics that are current interest and have enjoyed a high level of recent significant contributions.

The first article is on ***Mixed Boundary Value Problems in Mechanics*** and is by F. Erdogan of Lehigh University. After a general description of the basic features of mixed boundary value problems and relevant concepts, the author considers methods used to solve such problems. The direct application of complex potentials in solid mechanics is briefly described, and the technique of reducing the problem to a Riemann-Hilbert boundary value problem is formulated. The method of reducing the multiple series and multiple integral equations to singular integral equations is introduced. The emphasis of the article is on the numerical methods of solution of the resulting singular integral equations. Solutions to sample problems are included to demonstrate the application of the methods developed.

The second article, ***On the Problem of Crack Extension in Brittle Solids,*** is by K. Palaniswamy and W.G. Krauss of the California Institute of Technology. The problem of crack extension in a solid under arbitrary loads is discussed. Emphasis is on the crack growth that leads from a two-dimensional to a three-dimensional configuration. The line crack in an infinite elastic plane is considered; it is assumed that an energy balance criterion appropriately describes brittle fracture behavior. The stress analysis is performed via a Kolosov-Muskhelishvili method. Results are compared with those obtained from experiments as well as those obtained analytically by other investigators.

The third article by S.K. Datta of the University of Colorado is on the subject of ***Scattering of Elastic Waves.*** It describes various inclusion methods for solving the problem. The eigenfunction expansion is used to solve scattering by a fluid sphere or circular cylinder. The method of matched asymptotic expansions is followed by a section on the use of integral equations to solve a scattering problem by a rigid circular disc.

The fourth article by Y.H. Pao of Cornell University is entitled ***Electromagnetic Forces in Deformable Continua.*** The interaction between an electromagnetic field and a deformable body is analyzed. Various theories are constructed to develop a realistic model of the field-matter interaction. The theories are compared and critically reviewed. Two theories and a complete set of field equations, boundary conditions, and constitutive equations are summarized. The first theory is based on the Lorentz theory of electrons and statistical principles; the second theory postulates a two-dipole model for electrical polarization and magnetization.

The fifth chapter by F.C. Moon of Cornell University is on the subject of ***Problems in Magneto-Solid Mechanics.*** This article introduces researchers in mechanics to problems involving solids carrying high electric currents or placed in magnetic fields of high intensity. Such problems arise in the design of reactors for magnetic containment of fusion and to magnetic forming of metals using pulsed fields. The instability of solid structures in magnetic fields is emphasized. Both theoretical and experimental results are described in detail. This article is an excellent source of problems in magneto-solid mechanics including analytical and numerical methods for handling the nonlinear mathematics needed to understand the interaction of lasers, arcs, and electron beams with elastic media.

The sixth and last chapter by S. Nemat-Nasser of Northwestern University is the continuation of an

earlier article published by the same author in the second volume of **Mechanics Today. *On Nonequilibrium Thermodynamics of Continua: Addendum*** shows that the implications of the second law of thermodynamics as developed in the earlier article are too restrictive to describe the macroscopic behavior of materials in many commonly used models. In addition, the consequences of material stability are given, and restrictions on the evolutionary equations are explored.

This volume, published on behalf of the American Academy of Mechanics, developes the subject matter so that each article is useful to the specialist, but accessible to the nonspecialist who wants an introduction into research results in a new subject area.

This text is highly recommended to analytically-oriented engineers and scientists interested in applied mathematics and mechanics.

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MECHANICS TODAY, VOLUME 5

S. Nemat-Nasser, Editor
Pergamon Press, Inc., Elmsford, NY; 1980

The format of this volume of **Mechanics Today** differs from the previous ones, which contain about half a dozen state-of-the-art contributions by outstanding researchers in mechanics. Instead, it features 36 short articles by former students, colleagues, and associates of Eric Reissner to whom this volume was dedicated on the occasion of his 65th birthday.

A few of these contributions were presented at a symposium to honor Professor Reissner; it was held at the University of California, San Diego on June 23, 1978. A dedication to Professor Reissner appears at the beginning of the book and a list of his publications is presented at the end of the volume.

Because of the number of contributions, this reviewer must be content with whetting the appetite of the interested reader with a list of the first author and an abbreviated title of each article.

1. R.R. Archer et. al., ***Thick Rectangular Plates***
2. D. Bushnell, ***Aiming Electromagnetic Beams***
3. D.C. Drucker, ***Taylor Instability***
4. Y.C. Fung, ***Elasticity of Tissues***
5. A.L. Goldenveizer, ***Vibration of Shells***
6. G. Herrmann et. al., ***Layered Composites***
7. N.J. Hoff, ***Space Frameworks***
8. G.W. Housner, ***Earthquake Engineering***
9. M.W. Johnson, Jr., ***Polymer Liquids***
10. W.T. Koiter, ***Shell Theory***
11. E. Kroner, ***Random Media Elasticity***
12. T.J. Lardner et. al., ***Spherical Cells***
13. E.H. Lee, ***Plasticity***
14. H.E. Leipholz, ***Stability of Nonconservative Systems***
15. P.A. Libby, ***Premixed Turbulent Flames***
16. Y.Y. Lau et. al., ***Structure of Galaxies***
17. P. Mann-Nachbar, ***Singular Perturbation***
18. J.R. McLaughlin, ***Inverse Sturm-Lionville Problems***
19. J.W. Miles, ***The Second Painlevé Transcendent***
20. R.D. Mindlin, ***On Reissner's Equations***
21. H. Murakami et. al., ***Wave Propagation in Laminates***
22. S. Nair, ***Edge Solutions for Shells***
23. S. Nemat-Nasser et. al., ***Variational Methods***
24. T.H. Pian, ***Reissner's Principle***
25. A.C. Pipkin et. al., ***Crack Paths in Sheets***
26. R.S. Rivlin, ***Material Stability***
27. J.L. Sanders, Jr., ***Cylindrical Shells***
28. E.E. Sechler, ***Experiments in Shells***
29. P. Seide, ***Bending of Laminated Plates***
30. R.T. Shield, ***Uniqueness in Linear Elastostatics***
31. J.G. Simmonds, ***Stress Functions for Membranes***
32. C.R. Steele, ***Asymptotic Solutions for Shells***
33. F.Y. Wan, ***Dimpling of Spherical Caps***
34. K. Washizu, ***Complementary Energy***
35. H.J. Weinitschke, ***Nonlinear Elastic Membranes***
36. G.E. Widera et. al., ***Analysis of the Layered Tube***

It is remarkable that the contributors to this volume, whose names would appear in any compilation of a mechanics hall of fame should be counted among the students, colleagues, and associates of Professor Reissner. Analytically oriented engineers and scien-

tists in the shock and vibration community will find this volume a welcome addition to the current research literature.

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FATIGUE OF COMPOSITE MATERIALS

ASTM STP-569; PCN: 04-569000-33
ASTM, Philadelphia, PA
1975, 340 pages, $31.00

This special technical publication is a collection of 19 papers on the subject of composite materials fatigue. The papers were presented in December, 1973, at Bal Harbor, Florida. The range of materials dealt with are extensive, but all are technically classed as composites. A list of the articles follows:

1. ***Fatigue Crack Propagation Behavior of the Ni-Ni_3 CB Eutectic Composite,*** W.J. Mills and R.W. Hertzberg
2. ***Fatigue Crack Propagation in $0^\circ/90^\circ$ E-Glass/ Epoxy Composites,*** J.F. Mandell and Urs Meier
3. ***Reducing the Effect of Water on the Fatigue Properties of S-Glass Epoxy Composites,*** J.V. Gauchel, I. Steg, and J.E. Cowling
4. ***Fatigue Crack Growth in Dual Hardness Steel Armor,*** E.B. Kula, A.A. Anctil, and H.H. Johnson
5. ***Microcrack Growth in Graphite Fiber-Epoxy Resin Systems During Compressive Fatigue,*** S.C. Kunz and P.W.R. Beaumont
6. ***Nonlinear Response of Boron/Aluminum Angle-plied Laminates under Cyclic Tensile Loading: Contributing Mechanisms and Their Effects,*** C.C. Chamis and T.L. Sullivan
7. ***Effects of Frequency on the Mechanical Response of Two Composite Materials to Fatigue Loads,*** W.W. Stinchcomb, K.L. Reifsnider, L.A. Marcus, and R.S. Williams
8. ***Fatigue Behavior of Carburized Steel,*** R.W. Landgraf and R.H. Richman
9. ***Fatigue and Shakedown in Metal Matrix Composites,*** G.J. Dvorak and J.Q. Tarn
10. ***Fatigue Failure Mechanisms in a Unidirectionally Reinforced Composite Material,*** C.K.H. Dharan
11. ***High Strain Fatigue in a Ni(Cr)-TaC Fibrous Eutectic,*** M.F. Henry and N.S. Stoloff
12. ***Fatigue Behavior of an Ag_3Mg-AgMg Eutectic Composite,*** Y.G. Kim, G.E. Maurer, and N.S. Stoloff
13. ***Effects of Environment on the Fatigue of Graphite-Epoxy Composites,*** H.T. Sumsion and D.P. Williams
14. ***Flexural-Fatigue Evaluation of Aluminum Alloy and Kraft-Paper Honeycomb-Sandwich Beams,*** N.L. Person and T.N. Bitzer
15. ***Foreign Object Damage and Fatigue Interaction in Unidirectional Boron/Aluminum-6061,*** T.D. Gray
16. ***Axial Fatigue Properties of Metal Matrix Composites,*** J.L. Christian
17. ***Debond Propagation in Composite-Reinforced Metals,*** G.L. Roderick, R.A. Everett, and J.H. Crews
18. ***Realism in Fatigue Testing: The Effect of Flight-by-Flight Thermal and Random Load Histories on Composite Bonded Joints,*** D.J. Wilkins, R.V. Wolff, M. Shinozuka, and E.F. Cox
19. ***Reliability After Inspection,*** J.R. Davidson

The papers by Mandell, Ganchel, Kunz, Dharan, Sumsion, and Stinchcomb deal with resin matrix composites. Papers by Chamis, Dvorak, Gray, Christian, and Stinchcomb are concerned with fiber-reinforced metal matrix composites. Mills, Henry, and Kim deal with eutectically formed (composite) materials. Of the remaining papers those by Kula, Landgraf, Person, and Roderick deal with sandwich materials; i.e., the behavior of gross quantities of different materials literally bonded or fused together. Wilkins deals with joint fatigue and Davidson with statistical procedures in reliability. These papers are general and could be applied to fatigue of any material or structure.

The article by Mills examines a unidirectionally solidified Ni-Ni_3Cb eutectic for resistance to room temperature four-point bending fatigue. Stress in-

tensity versus crack growth rate curves are developed. The fatigue behavior is examined; R, metallurgical variables, and prior thermal treatment are independent variables. Extensive SEM examinations of the fracture surfaces are made.

The Mandell article presents the development of a fatigue crack growth model based on a ligament-by-ligament forward movement of the crack tip. The article offers a means for predicting a complex phenomenon using a macroscopic basic element; i.e., the width of one or two yarns in a glass fabric.

The Gauchel article is similar to several prior studies conducted at N.R.L. in which the chemistry of formation of epoxy resin is shown to be important in protecting the glass reinforcing element of a composite against attack by water.

The Kula article is concerned with layered sandwich armor material. Kula traces crack growth in such a material and supplements the theory with studies of metal sandwich formed by three distinct processes.

The Kunz article deals with a microscopic investigation of the detailed progress of crack propagation in graphite/epoxy composites under comprehensive loads. The study and conclusions appear to be somewhat artificial and not very general. No photographs of actual cracks prior to terminal fracture are shown.

The Chamis article is concerned with the nonlinear deformation behavior of boron/aluminum composites. Chamis states that three separate mechanisms contribute to early nonlinear response: early aluminum matrix nonlinear response, premature random fiber fractures, and ply-relative rotations. The article concentrates on the last mechanism. The theory is supplemented with a substantial experimental data base. It is a well-balanced paper written in a clear and interesting style and provides substantial insight into large strain fatigue. It is not clear that the same mechanism would operate for low-amplitude, high-cycle fatigue.

Stinchcomb reports on a nonlinear frequency dependence in failure of boron/aluminum composites. Prior work indicates a frequency dependence that is not nonlinear. The author calls for radical changes in current fatigue theory, but this conclusion is unwarranted on the basis of the limited data presented.

The Landgraf and Richman article elaborates a systematic approach to an investigation of the mechanical properties that affect the fatigue resistance of surface-hardened steel components. Dvorak and Tarn propose several simple load-deformation models for elastoplastic behavior in the matrix, including shakedown, under imposed cyclic loads. The authors show that the fatigue limits of several composites coincide with the composite shakedown limits because the matrix yield stresses and fatigue limits are equal.

Dharan deals with the problem of fatigue mechanisms over the entire range of cyclic lives. He distinguishes three principal ranges. For less than 200 cycles, fatigue behavior depends on fiber strength and the distribution of strengths about the mean. From 200 to 10^6 cycles an almost linear relationship exists between log stress and log cycles. Beyond 10^6 cycles, most of the cycles are required to nucleate cracks, and few failures occur. The article is a reasonably good blend of experimental results and failure analysis.

Henry and Stoloff describe a Ni(Cr)-TaC eutectic composite subject to high-strain, low-cycle fatigue. SEM examinations supplement strain-range fatigue analysis. The Coffin-Manson law applies.

Kim, Maurer, and Stoloff describe an Ag_3Mg-AgMg eutectic composite subject to strain-controlled fatigue. SEM examinations of crack growth are the principla means of examining the composite.

Sumsion and Williams utilized a decrease-in-stiffness criterion for failure of uniaxial and cross plied graphite/epoxy composites subject to repeated flexure and torsion stress cycles. The torsion results are interesting, but the analysis appears to be less than adequate. The torsion samples are not easily stress analyzed and are not conventional.

Person and Bitzer describe a detailed study of aluminum and kraft paper honeycomb sandwich beam fatigue tests. The paper is of particular importance to individuals interested in fatigue mechanisms of sandwich structures.

Gray describes a test effort aimed at the complex interaction of fatigue influenced by prior impact. The materials studied were 6061 aluminum/boron

composites. Christian describes the results of a fatigue test program for 6061 aluminum/BorSic, stainles steel/boron/6061 aluminum, stainless steel/6061 aluminum/BorSic, 6061 aluminum/titanium/BorSic, and 6A1-4V titanium/BorSic composites.

Roderick, Everett, and Crews used a fracture mechanics approach to investigate debonding of a graphite or S-glass composite from aluminum. Both experimental results and analysis are included.

The article by Wilkins, Wolff, Shinozuka, and Cox describes a complex fatigue experiment and analysis that can synthesize the mechanism of fatigue failure due to the combined effects of moisture, temperature, and spectrum loads. The results make it possible to use a realistic test and couple it with a reliability analysis. This well-written article is a definite contribution to the burgeoning composite fatigue literature.

The Davidson article seems out of place in the symposium. It has nothing to do with composites per se but deals instead with the important but separate issues of quality control, reliability, and flaw inspectability.

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SHORT COURSES

JUNE

VIBRATION DAMPING

Dates: June 14-17, 1982
Place: Dayton, Ohio
Objective: The utilization of the vibration damping properties of viscoelastic materials to reduce structural vibration and noise has become well developed and successfully demonstrated in recent years. The course is intended to give the participant an understanding of the principles of vibration damping necessary for the successful application of this technology. Topics included are: damping fundamentals, damping behavior of materials, response measurements of damped systems, layered damping treatments, tuned dampers, finite element techniques, case histories, and problem solving sessions.

Contact: Michael L. Drake, Kettering Laboratory 23, 300 College Park Avenue, Dayton, OH 45469 - (513) 229-2644.

METAL MATRIX COMPOSITES

Dates: June 14-18, 1982
Place: Los Angeles, California
Objective: The course provides an up-to-date overview of key aspects of metal matrix composites (MMC) technology that should enable the engineer and scientist to: evaluate the many MMC systems and competing materials for specific applications; develop test methods and evaluate data quality; develop reliable designs; fabricate reliable structures; and define research and material development requirements.

Contact: Short Course Program Office, UCLA Extension, P.O. Box 24901, Los Angeles, CA 90024 - (213) 825-1295.

COMPUTER-AIDED DESIGN OF DYNAMIC SYSTEMS

Dates: June 14-18, 1982
July 12-16, 1982
Place: East Lansing, Michigan
Objective: This course presents a structured approach to model building, formulation of state equations, and computer-aided analysis of the models. Applications are drawn from mechanical, electrical, hydraulic, thermal, and mixed-energy systems. Participants get hands-on experience with interactive graphics in engineering design.

Contact: Dr. Ronald C. Rosenberg, Program Director of the A.H. Case Center for Computer-Aided Design, College of Engineering, Michigan State University, East Lansing, MI 48824 - (517) 355-6453.

MECHANICS OF HEAVY-DUTY TRUCKS AND TRUCK COMBINATIONS

Dates: June 21-25, 1982
Place: Ann Arbor, Michigan
Objective: The heavy truck or truck combination is a complex pneumatic-tired system. This course presents analysis programs, parameter measurement methods and test procedures useful in understanding and designing a vehicle. The course describes the physics of heavy-truck components that determine the braking, steering and riding performance of the total system.

Contact: Engineering Summer Conferences, 400 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490.

COMPUTER-AIDED METHODS FOR MODAL ANALYSIS

Dates: June 21-25, 1982
July 19-23, 1982
Place: East Lansing, Michigan
Objective: This course introduces both finite elements and modal testing, emphasizing this common theory and pointing out the particular advantages of each method. Hardware includes the GenRad 2507, the Hewlett Packard 5423, and the PRIME 750. Software includes ANSYS, MODAL, PLUS, and SUPERTAB.

Contact: Dr. James Bernard, Director for the Case Center for Computer-Aided Design, College of Engineering, Michigan State University, Michigan State University, East Lansing, MI 48824 - (517) 355-6453.

JULY

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: July 19-23, 1982
Place: England
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

AUGUST

MACHINERY VIBRATION ANALYSIS

Dates: August 17-20, 1982
Place: New Orleans, Louisiana
Dates: November 9-12, 1982
Place: Oak Brook, Illinois
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow speed paper rolls.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

SEPTEMBER

SIMULATION AND ANALYSIS OF COMPLEX MECHANICAL SYSTEMS

Dates: September 6-10, 1982
Place: Northampton, UK
Objective: The goal is to assist participants in becoming proficient in the formulation of equations of motion of complex mechanical systems. With this background, the participants will be able to produce efficient algorithms for the simulation of motions and for the determination of constraint and control forces arising in connection with such systems.

Contact: The Open University, Walton Hall, Milton Keynes, MK7 6AA, Telephone: Milton Keynes 653945, Telex: 825061.

ELEVENTH ADVANCED NOISE AND VIBRATION COURSE

Dates: September 13-17, 1982
Place: Southampton, UK
Objective: The course is aimed at researchers and development engineers in industry and research establishments, and people in other spheres who are associated with noise and vibration problems. The course, which is designed to refresh and cover the latest theories and techniques, initially deals with fundamentals and common ground and then offers a choice of specialist topics. There are over thirty lectures, including the basic subjects of acoustics, random processes, vibration theory, subjective response and aerodynamic noise, which form the central core of the course. In addition, several specialist applied topics are offered, including aircraft noise, road traffic noise, industrial machinery noise, diesel engine noise, process plant noise and environmental noise and planning.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton S09 5NH, UK - Telephone - (0) (703) 559122 X 2310/752; Telex - 47661 SOTON UN G.

COMPUTER VIBRATION ANALYSIS

Dates: September 21-24, 1982

Place: Naperville, Illinois

Objective: The course deals with the role of the digital computer in solving vibration problems that arise in design, development, and fault diagnosis; fracture analysis is covered in depth. Applications of the computer to vibration problems associated with modeling, computation, and data handling are reviewed. Selection and use of hardware and software for computer analysis are discussed. The course begins with a review of vibration theory and a discussion of the types of vibration analysis available. Methods for obtaining and processing the physical data necessary to construct hardware models are described. Readily available and practical short computer programs are summarized, as are such large dynamic programs as NASTRAN, SAP, and ANSYS. Applications of these programs -- including pre-processors and post-processors -- are elaborated. Methods for predicting vibration failures that utilize fracture mechanics and finite element crack models are applied to such practical problems as generator motors. Available time-sharing services and the computer equipment required for such time sharing are discussed. Microcomputer hardware and software are reviewed and their capabilities summarized.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

TORSIONAL VIBRATIONS

Dates: September 28-30, 1982

Place: Oak Brook, Illinois

Objective: The course emphasizes methods for diagnosing and solving torsional vibration problems in existing equipment. Methods for controlling and eliminating torsional vibrations during the machinery design process are also described. Examples and case histories are used to illustrate mathematical and experimental techniques. The introductory lectures include a short review of basic torsional vibration concepts and a classification of excitations from various types of machines. A discussion of natural frequencies, mode shapes, critical speeds, and torsional vibration response includes the relationship of these factors to mechanical design and analysis. Such criteria for evaluating torsional vibration as strength and motion are discussed, as is the application of these criteria to solving machine problems; allowable stresses and motions are given. Requirements, sources, and techniques for measuring and calculating parameters for the acquisition of design data are topics for several lectures. Data from blueprints and physical measurements are used to model systems and components for such parameters as stiffness, damping, and mass. Models of physical systems, explicit formulas, and the Holzer method are used to calculate such parameters as natural frequencies and mode shapes. Several lectures are devoted to steady and transient forced vibration responses and include the measurement and analysis of motions and stresses. Techniques involved in premeasurement, calibration of sensors, and actual measurement of forced vibration are discussed and demonstrated. Case histories are used to illustrate what, where, and how to measure and analyze specific torsional vibration problems on such components as pumps, compressors, gearboxes, engines, motors, and couplings. Torsional/lateral interactions in rotors, gearboxes, and pumps are described. Such techniques of vibration control as tuning, reduction of excitation, damping, and isolation are elaborated. Selection of the proper coupling for vibration control and for capability to prevent misalignment is emphasized.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

NOISE CONTROL ENGINEERING ISSUES CURRENT CONTENTS

NOISE CONTROL ENGINEERING, the technical publication of the Institute of Noise Control Engineering contains articles of wide interest to noise control engineers. The following articles appear in the March-April issue (Vol. 18, No. 2):

- ***Radiation Impedance of an Unflanged Pipe with Mean Flow*** by V.B. Panicker and M.L. Munjal
- ***The Impact and Future Direction of Aircraft Noise Certification*** by M.J.T. Smith
- ***Noise Generation by Oil-Burner Heads with Pressure Jet Atomization*** by P. Anglesio and E. Cirillo
- ***Effect of Interrupted Flow on Traffic Noise*** by Kenneth R. Agent and Charles V. Zegeer

NOISE CONTROL ENGINEERING is published bimonthly by INCE. The subscription rate is $35.00 per year for libraries and institutions. Individual subscribers become Associates of the Institute and receive the bimonthly publication NOISE/NEWS in addition to NOISE CONTROL ENGINEERING. There is an extra charge for shipment overseas and to Canada/Mexico.

Further information and specimen copies may be obtained from INCE, P.O. Box 3206, Arlington Branch, Poughkeepsie, NY 12603.

ERRATUM

The following reference appeared incorrectly on page 7 of Volume 14, No. 1, January, 1982, "The Literature of Vibration Engineering" by Neville F. Rieger.

Rieger and Crofoot [66], Page 7

66. Rieger, N.F. and Crofoot, J.C., Vibrations of Rotating Machinery, Volume I, Rotor-Bearing Dynamics, Vibration Institute, Clarendon Hills, IL (1977).

ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, DC 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

ABSTRACT CONTENTS

MECHANICAL SYSTEMS

ROTATING MACHINES

(Also see No. 1007)

82-928

Nonlinear Torsional Vibration in Synchronous Motor Driven Systems (1st Report, Analysis, Experiment, and Field Test)

Y. Inoue, T. Shibata, T. Fujikawa, and M. Takemura
Mech. Engrg. Res. Lab., Kobe Steel Ltd., Wakinohamacho, Chuo-ku, Kobe, Hyogo, Japan, Bull. JSME, 24 (197), pp 2003-2012 (Nov 1981) 18 figs, 4 tables, 13 refs

Key Words: Rotating machinery, Synchronous motors, Torsional vibration, Backlash effects

During the start-up of synchronous motor driven systems, resonant torsional vibration can be caused by the pulsating torque of the motor. A method of nonlinear transient analysis for this problem, using a digital computer, is proposed which can treat the effect of backlash and save computation time. The calculated results of this method are in good agreement with experimental and field test data. The vibration phenomena of such systems are examined thoroughly, and some different aspects between the response of nonlinear systems which include backlash and that of linear systems are shown.

82-929

Influence of Unequal Pedestal Stiffness on the Instability Regions of an Asymmetrical Rotor

H. Ota and K. Mizutani
Nagoya Univ., Chikusa-ku, Nagoya, 464, Japan, Bull. JSME, 24 (198), pp 2133-2140 (Dec 1981) 8 figs, 8 refs

Key Words: Rotors, Supports, Variable material properties, Asymmetric bodies

A shaft carrying an asymmetrical rotor is supported by upper and lower flexible bearing pedestals each of which has a directional inequality of stiffness $\epsilon = 0 \sim 1$ and a concentrated mass. The analysis of this problem is carried out on the assumption that ϵ is either negligibly small or not so. The positions, width and number of unstable regions are analytically determined. The analytical results show a good coincidence with results obtained by an analog computer.

82-930

A Full-Scale Wind Tunnel Investigation of a Helicopter Bearingless Main Rotor

W. Warmbrodt and J.L. Mccloud
NASA Ames Res. Ctr., Moffett Field, CA, Rept. No. NASA-TM-81321, A-8696, 287 pp (Aug 1981) N81-32137

Key Words: Rotors, Bearingless rotors, Helicopters, Wind-tunnel testing

A helicopter bearingless main rotor was tested. Areas of investigation included aeroelastic stability, aerodynamic performance, and rotor loads as a function of collective pitch setting, RPM, airspeed and shaft angle. The rotor/support system was tested with the wind tunnel balance dampers installed and, subsequently, removed. Modifications to the rotor hub were tested. These included a reduction in the rotor control system stiffness and increased flexbeam structural damping. The primary objective of the test was to determine aeroelstic stability of the fundamental flexbeam/blade chordwise bending mode.

82-931

Method of Enhancing Rotor Bore Cyclic Life

T.A. Brisken
Dept. of the Air Force, Washington, DC, PAT-APPL-6-270 051, 13 pp (June 3, 1981)

Key Words: Rotors, Fatigue life

This invention relates to a method of enhancing or prolonging the low cycle fatigue life of the bore area of a rotating disk. The method comprises the step of prestressing the bore area by heating the web/rim area of the disk, while moderately overspeeding the disk. The heating can be accomplished with the use of induction heating coils which are disposed adjacent the web/rim area of the disk. This method, unlike prior art prestressing methods, is simple to perform, is cost effective, and does not compromise the disk or the design of the assembly of which the disk is a component.

82-932

Failure Analysis of a Rotating Stub Shaft

B.D. Busch and T.A. Jur
Amoco Chemicals Corp., Mt. Pleasant, SC, ASME Paper No. 81-WA/DE-8

Key Words: Shafts, Failure analysis, Design techniques

Post failure design analysis is increasingly being used as an engineering design tool as engineers discover that there is a great deal to be learned from a thorough analysis of a failed part. This paper reviews the post failure analysis of a rotating stub shaft as a case in point. The work done by an engineer in the field is examined on the basis of proven design techniques and the application of engineering judgment.

82-933

Simplified Mathematical Models for the Simulation of Wheel Set Motion (Die Zulässigkeit vereinfachter Rechenmodelle zur Simulation des Radsatzlaufes)

H.-P. Friedrich

Lehrstuhl f. Eisenbahnmaschinenwesen, Technische Universitat Munchen, Germany, Fortschritt-Berichte VDI-Zt., Reihe 11 (44) (1981), 138 pp, 59 figs, 8 tables, 84 refs. Summarized in VDI-Z., 123 (20), p 861 (Oct 1981). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany, Price 84 DM (In German)

Key Words: Mathematical models, Interaction: rail-wheel

The limits of simplification of a mathematical model for a wheelset-rail vibration system, which would provide sufficient data, are investigated. Evaluation criteria are shaft motion frequency and the damping or limit velocity of the wheelset. The author concludes that if the friction values between the wheel and rail are accurately known, the shaft motion frequency of the wheelset can be determined by means of a very simple model. The stability of the wheelset can be determined exactly, when as many as possible horizontal degrees of freedom are taken into consideration and the friction and all the remaining data are determined.

82-934

Effect of Cooling System Design on Truck Noise

M.A. Staiano and R.A. Major

ORI, Inc., Silver Spring, MD, Rept. No. ORI/TR-1863, EPA-550/9-81-319, 103 pp (Jan 1981) PB82-101148

Key Words: Fan noise, Trucks

Improving cooling system performance, thus reducing the fan aerodynamic requirement, is a key to quieter fans. Relative to an existing gasoline-engined medium truck cooling system, increased top tank temperature permits an airflow reduction estimated to allow an 11 dB reduction in fan noise. Use of a multi-pass radiator in this configuration adds a further 1.5 dB reduction, as estimated in a non-optimized case. Fan aerodynamic and acoustical performance is most significantly improved by reducing blade tip-to-shroud clearance. Fan designs which include integral (rotating) shrouds provide the best aerodynamic performance and least noise. Alternatively, low tip clearance fans using fixed engine-mounted shrouds or radiator-mounted fans (driven by a flexible coupling), will also provide superior performance.

82-935

How to Calculate Critical Speed in Centrifugal Pumps

S. Gopalakrishnan, R. Fehlau, and J. Lorett

Byron Jackson Pump Div., Borg-Warner Corp., Los Angeles, CA, Oil Gas J., 79 (49), pp 113-119 (Dec 7, 1981) 14 figs, 5 refs

Key Words: Pumps, Centrifugal pumps, Lubrication, Critical speeds

This article provides a simplified method for calculating wet critical speed of pumps. A theoretical formulation for critical speed calculation is presented which was verified in a test arrangement.

RECIPROCATING MACHINES

82-936

Vibration Analysis of Movable Part of Internal Combustion Engine (Part 1. Crank Shaft)

A. Nagamatsu and M. Nagaike

Bull. JSME, 24 (198), pp 2141-2146 (Dec 1981) 10 figs, 2 tables, 3 refs

Key Words: Internal combustion engines, Crankshafts, Natural frequencies, Mode shapes, Impedance technique

Natural frequencies, natural modes and dynamic response of a crank shaft of an internal combustion engine are analyzed by the reduced impedance method proposed by the author. A crank shaft is divided into straight shaft parts and arm parts. The dynamic behavior of the straight shaft part is expressed first by the transfer matrix, which is transformed into the reduced impedance matrix. The arm part is divided into the tetrahedral elements by the finite element method, and the degrees of freedom of their boundary surface parts

are reduced to six. The equation of motion of the arm part is reduced to form a reduced impedance matrix with respect to the boundary parts. The reduced impedance matrices of all components are combind to give a global equation of motion of the crank shaft, and this equation is solved to get natural frequencies, natural modes and dynamic response. The calculated results agree well with the experimental ones.

82-937

Acoustic and Emission Characteristics of Small, High-Speed Internal Combustion Engines

D. Morrison and R.V. Karsick

Calspan Advanced Tech. Ctr., Buffalo, NY, Rept. No. DOT-HS-805 830, DOT-TSC-NHTSA-81-11, 362 pp (July 1981)

PB82-104225

Key Words: Engine noise, Noise reduction

The intent of this study is to obtain information on small high-speed engines so that their effect on the urban environment may be assessed, and if necessary, programs devised to reduce the noise and other emissions from vehicles using these highly desirable and efficient power plants.

METAL WORKING AND FORMING

82-938

Drop Forging: Noise Reduction and Automatic Control Equipment. January, 1973 - October, 1981 (Citations from the Information Services in Mechanical Engineering Data Base)

NTIS, Springfield, VA, 51 pp (Oct 1981)

PB82-853698

Key Words: Forging machinery, Metal working, Noise reduction, Bibliographies

The forming of metals by drop forging is discussed in terms of the effects of noise and vibration on workers as well as the use of automatic control equipment for more precise forging and material handling.

82-939

Noise Reduction Processes in Cutting with High-Speed Tools

H.K. Töenshoff, A. Scherger, and R. Westphal

Inst. for Production Engrg. and Metal-Cutting Tools, Universität Hannover, Welfengarten 1A, 3000 Hannover, West Germany, Noise Control Engrg., 17 (3), pp 126-131 (Nov-Dec 1981) 9 figs, 1 table, 6 refs

Key Words: Cutting, Metal working, Noise reduction

A-weighted sound levels of up to 110 dB are created by circular sawing of metal, stone slotting and manual grinding. In manual grinding the noise excitation comes from the contact of individual abrasive grains. In stone slotting and circular sawing the blades are excited by the wheel speed in the axial direction in the kerf (a slit or notch made by a cutting disk). The best measures for reducing noise are examined. These measures include enclosure of the tools and the use of tools with a laminated structure (with or without plastics). The damping effect of systems without plastics is based on viscosity damping in the air layer. Due to near-field radiation, no further reduction in noise can be achieved by raising the loss factor above 0.01 to 0.02.

STRUCTURAL SYSTEMS

BRIDGES

(See No. 1014)

BUILDINGS

(Also see Nos. 1027, 1071)

82-940

Coupled Motion of Wind-Loaded Multi-Story Building

J.N. Yang, Y.K. Lin, and B. Samali

Dept. of Civil, Mech. and Environmental Engrg., George Washington Univ., Washington, DC 20052, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1209-1226 (Dec 1981) 5 figs, 1 table, 14 refs

Key Words: Buildings, Multistory buildings, Wind-induced excitation, Translational response, Torsional response, Coupled response, Statistical analysis

An analytical procedure is developed to compute the statistical properties of structural response of a slender tall building under the excitation of a random wind flow field which is statistically stationary in time and nonhomogeneous in

space. The mass, elastic, and aerodynamic axes of the building are assumed to be different. Therefore, the translational and the torsional motions of the building are coupled. The problem is formulated in terms of transfer matrices, which relate the response at one floor to the next floor. A numerical example of a 40-story building is given to illustrate the applications.

82-941

Application of Inelastic Response History Analysis in the Aseismic Design of a 31-Storey Frame-Wall Building

M. Fintel and S.K. Ghosh

Portland Cement Assn., Skokie, IL, Earthquake Engrg. Struc. Dynam., 9 (6), pp 543-555 (Nov-Dec 1981) 7 figs, 1 table, 17 refs

Key Words: Buildings, Multistory buildings, Seismic design

Aseismic design of a 31-story reinforced concrete building is carried out on the basis of inelastic response history analyses under carefully selected input motions. The design approach makes it possible to predetermine the sequence of plastification, provide ductility details only where required, and balance the strength and ductility requirements of individual members. Efficiency, economy and desired structural performance are achieved as a result.

82-942

Mixed Finite Element Method for Efficient Optimal Design of Earthquake Resistant Structures

F.M. El-Kamshoshy

Ph.D. Thesis, Univ. of California, Berkeley, CA, 149 pp (1981)
UM 8200086

Key Words: Buildings, Multistory buildings, Earthquake resistant structures, Seismic design, Finite element technique

The development of a mixed finite element method useful for efficient optimal design of earthquake resistant structures is presented. For coupled shear walls and unbraced multistory frames, subject to a wide range of equivalent static design loads as well as the effect of gravity, the method efficiently computes the inelastic structural response, derivative of the lateral displacement of the top floor with respect to the moment capacity of the developed plastic hinges, and derivatives of the yield angles (angular discontinuities) of the plastic hinges with respect to their moment capacity. To verify the efficiency of the method, numerical tests are conducted on coupled shear walls and unbraced frames. In all the numerical tests, complete convergence of the inelastic solution is obtained after four iterations. The application of the method to the study of eccentrically braced frames, more general constitutive relations, and other structures is also outlined.

82-943

Distribution of Maximum and Statistical Response Spectra

J.N. Yang and S.C. Liu

Dept. of Civil, Mech., and Environmental Engrg., George Washington Univ., Washington, DC, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1089-1102 (Dec 1981) 7 figs, 20 refs

Key Words: Multistory buildings, Buildings, Equipment response, Seismic design, Spectral energy distribution techniques, Random vibration

The concept of response spectra is extended and applications broadened by investigating the relevant aspects of the maximum structural response based on the random vibration theory. The asymptotic distributions of both stationary and nonstationary maximum structural responses are established and compared with the results of Monte Carlo simulation. Applications of the statistical distributions of maximum response in the development of design response spectra of building-equipment systems and in the dynamic analysis of tall buildings are demonstrated.

82-944

Dynamic Properties of a Twelve Story Prefabricated Panel Building

J.G. Bouwkamp, J.P. Kollegger, and R.M. Stephen

Earthquake Engrg. Res. Ctr., Univ. of California, Berkeley, CA, Rept. No. UCB/EERC-80/29, NSF/RA-800596, 110 pp (Oct 1980)
PB82-117128

Key Words: Buildings, Multistory buildings, Resonant frequencies, Damping, Mode shapes, Interaction: structure-foundation

The results of forced and ambient vibrations studies of a twelve story apartment building, constructed with prefabricated wall panel and slab elements are presented. Dynamic characteristics, such as resonant frequencies, damping, and vertical and horizontal mode shapes of the structure were determined and correlated with analytical results using the

computer program TABS-77. Rigid floor diaphragm action and serious structure-foundation interaction were observed. Including the foundation flexibility in the analytical model using experimental vibration data resulted in resonant frequencies and mode shapes showing excellent agreement with the test data.

82-945

Earthquake Analysis of Soil-Structure Systems Utilizing Fourier Transform Techniques

T.O. Weaver

Ph.D. Thesis, Univ. of Virginia, 124 pp (1980)
UM 8129317

Key Words: Buildings, Interaction: soil-structure, Seismic excitation, Fourier transformation

A computational procedure, based on Discrete Fourier Transform theory, was developed to determine the transient response of structures subjected to earthquake excitation, in which the effects of soil-structure interaction are included. Present analysis procedures for this type of problem utilize Fourier Transforms but require the complete solution of the equations of motion in the frequency domain for each frequency increment. This approach is exceedingly time consuming. The method presented herein provides a much more efficient means of calculating the steady state response of the system. The key feature of the method is to equate the moment exerted by the structure on the foundation to the resistance developed by the foundation and supporting soil. This makes it possible to solve only for the steady state response of the base. The structural response is then obtained by applying a base excitation which is a combination of the earthquake ground motion and the known base response. This is done by standard modal analysis.

82-946

Flexible Sub-Surface Building-Foundation Interfaces for Aseismic Design (Preliminary Studies)

E. Raupach, B. Schumacker, and J.M. Biggs

Dept. of Civil Engrg., Massachusetts Inst. of Tech., Cambridge, MA, Rept. No. R81-8, NSF/CEE-81020, 138 pp (Apr 1981)
PB81-243891

Key Words: Buildings, Flexible foundations, Seismic design

The feasibility of constructing buildings on horizontally flexible foundations to mitigate the effects of earthquakes is explored. The specific concept studied involves the use of slender steel piles enclosed in sleeves to permit flexural distortion. Piles are designed by a simple procedure using smoothed response spectra. The performance of the designed systems are then studied using time histories of actual ground motions. The report includes descriptions of ground motions used in the study, pile design equations and procedures, and the time-history analysis.

82-947

Urban Seismic Risk: Analysis and Mitigation. An Inquiry into Structural and Locational Approaches to Minimizing Seismic Damage, Employing Probabilistic Response Spectra

C.R. Scawthorn

Ph.D. Thesis, Kyoto Univ., Japan, 205 pp (1981)
UM 8129821

Key Words: Buildings, Earthquake damage, Damage prediction

This dissertation analyzes urban seismic risk, defined as expected damage, and investigates techniques for mitigating this damage, using the Osaka, Japan region as a case study. Seismic hazard is determined in terms of probabilistic response spectra, employing extreme value statistics and determining the maximum response spectral acceleration with an annual probability of exceedance of 0.01 to be 0.5 g at a frequency of 4 Hz.

82-948

A Dual Criteria Approach for Optimal Design of Earthquake-Resistant Structural Systems

M.A. Bhatti and K.S. Pister

Univ. of California, Berkeley, CA, Earthquake Engrg. Struc. Dynam., 9 (6), pp 557-572 (Nov-Dec 1981)
16 refs, 16 figs

Key Words: Buildings, Earthquake resistant structures, Seismic design, Design techniques, Min-max technique, Energy absorption, Isolators

This paper presents a formulation for earthquake-resistant design of structural systems. Based upon current design philosophy, two levels of performance constraints are imposed as follows. For minor earthquakes which occur more frequently, the structure is constrained to remain elastic with no structural damage. For less frequent, major earthquakes, the structure can undergo inelastic deformations, with limited damage. The design problem is formulated as a min-max problem, and a general strategy to transcribe it

to the canonical form of a non-linear programming problem is given. Several design problems with different performance criteria are considered and the results compared to assess the effect of these different criteria.

82-949

Seismic Evaluation Criteria for Existing Critical Industrial Facilities

W.E. Manrod, W.J. Hall, and J.E. Beavers
Oak Ridge Gaseous Diffusion Plant, TN, Rept. No. K-BD-1053, CONF-810934-1, 20 pp (1981) (Pres. at Conference on earthquakes and earthquake engineering: the Eastern United States, Knoxville, TN, Sept 14, 1981)
DE8 1028336

Key Words: Industrial facilities, Seismic analysis

Guidelines for the development of seismic evaluation criteria for existing critical industrial facilities are presented. Critical industrial facilities are considered as those facilities that, if damaged by natural phenomena, could result in the release of substances harmful to the public or the environment, or that could result in what owners consider as unacceptable financial losses. The guidelines are intended to assist in developing evaluation criteria for such facilities, which will result in realistic assessments that are representative of the state-of-the-art.

FOUNDATIONS

82-950

Dynamic Analysis of Shallow and Pile Foundations

M.A. Sheta
Ph.D. Thesis, The Univ. of Western Ontario, Canada (1981)

Key Words: Pile foundations, Interaction: soil-structure, Harmonic excitation, Transient excitation, Random excitation

Structural response to the effects of earthquakes, wind, operating machines and dynamic loads from other sources is often affected by soil-structure interaction. An approach is presented to account for dynamic soil-structure interaction that makes it possible to consider approximately the effects of soil nonlinearity, slippage, and lack of bond. These factors as well as the effect of backfill of embedded foundations are accounted for by the inclusion of a cylindrical zone around the pile whose shear modulus and material damping differ from those of the outer medium. An approximate theory for vibration of pile groups is also presented. The results from dynamic field experiments with pile group are presented and compared with the theoretical predictions. A unified approach to the dynamic analysis of foundations to harmonic, transient and random loads is presented and incorporated into a general computer program.

82-951

Dynamic Pile Driving Measurements for University of Houston Pile Group Study

A.A. Dover, G.E. Locke, and J.M.E. Audibert
Woodward-Clyde Consultants, Houston, TX, Rept. No. FHWA/RD-81/009, 48 pp (Mar 1981)
PB81-245680

Key Words: Pile driving, Interaction: soil-structure

Dynamic measurements of strain and acceleration were made during pile driving operations on 11 piles using transducers attached near the top of the pile. The objective of the program was to collect pile driving data that could be utilized to assess hammer-pile-soil performance and interaction. Vertical load tests were conducted on a separate program on both a 9-pile group and two single piles as part of the overall FHWA research effort.

UNDERGROUND STRUCTURES

82-952

Earthquake Engineering of Large Underground Structures

G.N. Owen and R.E. Scholl
URS/John A. Blume and Associates, San Francisco, CA, Rept. No. JAB-7821, FHWA/RD-80/195, 299 pp (Jan 1981)
PB81-247918

Key Words: Underground structures, Tunnels, Seismic design

This study identifies and evaluates the current state of the art of earthquake engineering of transportation tunnels and other large underground structures. A review of the past performance of 127 underground openings during earthquakes indicates that underground structures in general are less severely affected than surface structures at the same geographic location. However, some severe damage, including

collapse, has been reported. The literature on the nature of underground seismic motion is reviewed in detail.

HARBORS AND DAMS

(Also see No. 1063)

82-953

Earthquake-Induced Longitudinal Strains and Stresses in Non-Homogeneous Earth Dams

A.M. Abdel-Ghaffar and A.-S. Koh

Dept. of Civil Engrg., Princeton Univ., Princeton, NJ, Earthquake Engrg. Struc. Dynam., 9 (6), pp 521-542 (Nov-Dec 1981) 14 figs, 3 tables, 13 refs

Key Words: Dams, Earthquake response, Longitudinal vibration

This paper deals with the problem of analyzing the longitudinal vibrational behavior of non-homogeneous earth dams during earthquakes. The principal objective of the investigation is to estimate earthquake-induced strains and stresses (both shear and normal or axial) in earth dams in a direction parallel to the dam axis using the analytical elastic models developed by the authors. The non-homogeneity of the dam materials is taken into account by assuming specific variations of both the shear modulus and the modulus of elasticity along the depth due to the confining pressure. Based on the analytical models, a rational procedure is developed to estimate dynamic stresses and strains and corresponding elastic moduli and damping factors for earth dams from their hysteretic responses to real earthquakes, utilizing the hysteresis loops from the filtered crest and base records.

82-954

Dynamic Analysis of Simple Arch Dams Including Hydrodynamic Interaction

C.S. Porter and A.K. Chopra

Dept. of Civil Engrg., Univ. of California, Berkeley, CA, Earthquake Engrg. Struc. Dynam., 9 (6), pp 573-597 (Nov-Dec 1981) 13 figs, 21 refs

Key Words: Dams, Arches, Cylindrical shells, Hydrodynamic excitation, Substructuring methods

The substructure method is adapted and generalized for response analysis of arch dams subjected to upstream-downstream, cross-stream and vertical components of ground motion. The arch dam is assumed to be a segment of a circular cylinder, bounded by vertical, radial banks of the river valley enclosing a central angle of 90°. The arch dam and impounded water are treated as two substructures of the total system and displacements of the dam are represented as a linear combination of the first few natural modes of vibration of the dam alone. For this simple geometry of the arch dam and fluid domain, mathematical solutions of the wave equation are presented to determine the hydrodynamic terms in the finite element equations for the dam. Responses to arbitrary ground motion can be obtained by Fourier synthesis procedures applied to the complex frequency response functions determined by the analysis procedures presented in this paper. Numerical results are presented for the complex frequency response functions for hydrodynamic pressures on rigid dams due to each of the three ground motion components. The variation of these pressures with excitation frequency, depth and circumferential location on the upstream face of the dam is studied. Results of an example analysis are presented.

82-955

Numerical Analysis of Harbor Resonance Response in East Channel, Los Angeles Harbor

D.G. Outlaw and J.R. Houston

Hydraulics Lab., Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. WES/MP/HL-81-3, 51 pp (June 1981)
AD-A103 426

Key Words: Numerical analysis, Harbors, Resonant response, Water waves

A hybrid finite-element numerical model was used to calculate harbor resonance, relative to that for existing conditions, for proposed non-Federal dredging adjacent to East Channel in the Port of Los Angeles. The numerical model yields convergent solutions for harbors of arbitrary shape and variable depth. The response of East Channel to long-period wave excitation was calculated over the 60- to 600-sec range for each plan.

CONSTRUCTION EQUIPMENT

82-956

An Inexpensive, Portable Vibracoring System for Shallow-Water and Land Application

K. Finkelstein and D. Prins

Coastal Engineering Res. Ctr., Fort Belvoir, VA, Rept. No. CERC-CETA-81-8, 16 pp (July 1981)
AD-A104 323

Key Words: Coring, Vibratory techniques, Construction equipment

A portable vibracoring system provides an efficient, rapid, and safe means of extracting cores up to 33 feet (10 meters) long. Short cores (< 10 feet or 3 meters long) are also obtained with a part of the system. This report describes the system and the coring procedures for intrusion, extraction, and packaging.

POWER PLANTS

(Also see Nos. 1046, 1063, 1097, 1098, 1099)

82-957

Estimation of Dynamic Equivalents of External Electric Power Systems

M.A.A. El-Sharkawi

Ph.D. Thesis, The Univ. of British Columbia, Canada (1980)

Key Words: Power plants (facilities), Mathematical models

The growing size and complexity of modern electric power systems necessitate the need to develop dynamic equivalents of the external system for local system dynamic studies. An estimation technique is developed in this thesis to identify the dynamic equivalents of external systems. Applying the developed techniques, equivalent parameters are estimated for three test systems, and results are included. The dynamic responses of the original systems and the equivalent systems are compared.

82-958

A Computing Technique for Hydraulic Resonance in Hydropower Plants with Surge Tanks

M. Popescu and A. Halanay

Hydraulic Engrg. Res. Inst., Bucharest, Romania, Mécanique Appliquée, 26 (3), pp 421-431 (May/June 1981) 3 figs, 8 refs

Key Words: Hydroelectric power plants, Harmonic excitation, Periodic response

For the study of hydraulic resonance in a system with admission gallery, surge tank and penstock, the general equations of the motion of the water are considered in the hypotheses of small harmonic perturbations at the plant level correspondingly described in the boundary conditions. For the linearized model around the steady state the response to harmonic excitations is computed by the method of characteristics, thus obtaining the resonance frequencies, corresponding to the maximal amplitudes of the variations of water pressure in the penstock at the turbine section. The frequencies obtained are tested by numerical simulation on the nonlinear mathematical model. An example of application of the method is described.

OFF-SHORE STRUCTURES

(Also see Nos. 1010, 1016)

82-959

Fatigue Life and Reliability of Ocean Systems Subjected to Random Loads

P.Y. Chang

Hydronautics, Inc., Laurel, MD, ASME Paper No. 81-WA/OCE-12

Key Words: Off-shore structures, Fatigue life, Random excitation

This paper presents a proposed methodology for the prediction of fatigue life and the reliability of ocean systems to random sea loads. The loads are represented by a series of wave spectra with different weighting factors and frequencies of occurrence. Unlike many existing methods based in the assumption and analysis of weakest elements, this method provides a probabilistic relationship between the fatigue life and probability of failure of different individual structural elements. A design procedure is proposed.

82-960

The Significance of Dynamic Response in the Estimation of Fatigue Life

J.K. Vandiver

Massachusetts Inst. of Tech., Cambridge, MA, ASME Paper No. 81-WA/OCE-13

Key Words: Off-shore structures, Fatigue life, Water waves, Modal damping

The fatigue life of offshore structures is investigated under the conditions that dynamic response to waves is assumed to play a significant role. Under these conditions, the study emphasizes the significance of the placement of natural frequencies and the amount of modal damping. The results may be used to assess the confidence bounds on fatigue life estimates that result from uncertainties in design stage estimates of structural natural frequencies and damping.

82-961

Nonlinear Dynamic Analysis of Guyed Tower Platforms

S.Y. Hanna, A. Mangiavacchi, and R. Suhendra
Brown & Root, Inc., Houston, TX, ASME Paper No. 81-WA/OCE-9

Key Words: Off-shore structures, Towers, Guyed structures, Interaction: structure-fluid, Time domain method

A method of analysis is presented to predict the nonlinear dynamic behavior of complaint offshore structures. The mathematical model is analyzed in time domain using the normal mode superposition approach. Nonlinearities due to fluid-structure interaction is introduced by the use of relative velocity terms between structure and fluid.

VEHICLE SYSTEMS

GROUND VEHICLES

(Also see Nos. 933, 976, 977, 1127)

82-962

Freight Car Dynamics

E.H. Law and N.K. Cooperrider
Dept. of Mech. Engrg., Clemson Univ., SC, Rept. No. FRA/ORD-81/47, 52 pp (Aug 1981)
PB82-116948

Key Words: Railroad cars, Freight cars, Dynamic response, Prediction techniques

The objective of this research project was to develop techniques to analyze the lateral dynamic behavior of railroad freight cars. The effort included development and correlation of theoretical techniques for predicting freight car dynamic behavior, and use of the techniques to investigate the behavior of present and proposed designs. A number of models and analysis approaches were developed for freight car behavior on tangent track. An output of the project is the understanding of the appropriate use of each model and analysis technique. Extensive field tests were conducted. Eight different vehicle configurations were tested, each at several speeds on both tangent and curved track. Data obtained from these tests were used for comparisons with theoretical predictions of vehicle response.

82-963

Lateral Dynamics of 70-Ton Freight Car Trucks

M.M. ElMadany and P.V. RamaChandran
Wyle Laboratories, Colorado Springs, CO, ASME Paper No. 81-WA/RT-2

Key Words: Railroad cars, Box cars, Hunting motion

As part of the ongoing Federal Railroad Administration sponsored Truck Design Optimization Project/Phase II, hunting of 70-ton capacity box-type cars equipped with standard three-piece trucks is studied using field data. The influence of operating parameters such as speed and lading conditions, as well as the effects of truck parameters such as wheel profiles, on the lateral stability of these freight cars are investigated.

82-964

Freight Car Dynamics: Field Test Results and Comparison with Theory

N.K. Cooperrider, E.H. Law, and R.H. Fries
Dept. of Mech. Engrg., Clemson Univ., SC, Rept. No. FRA/ORD-81/46, 142 pp (June 1981) (See also PB82-116948)
PB82-116930

Key Words: Railroad cars, Freight cars, Experimental test data, Modal damping, Natural frequencies, Mode shapes, Hunting motion

Field tests of a conventional rail freight car were conducted to provide data for comparison with theoretical analyses of rail freight car dynamic behavior. These tests were designed to provide experimental information concerning modal damping, modal frequencies, mode shapes, motion amplitudes, critical hunting speeds, wheel-rail forces, and creep coefficients for comparison with theoretical results. Alternative techniques for theoretical freight car analysis, data processing, and comparison of theory and experiment are discussed.

82-965

Pass-By Noise Analysis

T.F. Dunlap, R.C. Edstrom, and J.M. Ehlbeck
Freightliner Corp., Portland, OR, SAE Paper No. 810855

Key Words: Ground vehicles, Trucks, Noise generation

A system for analyzing results from vehicle pass-by noise tests is presented. Features of the system include data telem-

etry, narrow band frequency analysis, order analysis, portability and efficient data management through the use of computer based data reduction and display graphics. The system has been implemented and utilized in a development program for reduction of noise emissions from heavy-duty diesel trucks.

82-966

Truck Noise: Planning an Effective Compliance Program

B. Peterson
Kenworth Truck Co., SAE Paper No. 810854

Key Words: Trucks, Noise reduction

The EPA truck noise emission standard of 1978 made noise compliance a responsibility of each truck manufacturer. Various administrative and technical details of compliance are discussed. These include basic program organization, testing techniques, efficient use of acoustical materials and noise control components, and the use of computers to process data and select trucks for testing.

82-967

Noise Reduction of Heavy-Duty Trucks

E.K. Bender, R.L. Bronsdon, and P.J. Remington
Bolt, Beranek and Newman Inc., Cambridge, MA, SAE Paper No. 810852

Key Words: Trucks, Noise reduction

This paper describes the development of noise control treatments for two heavy-duty diesel trucks. Noise levels are reduced to 72 dBA when measured according to the SAE J366b Recommended Practice. The treatments, comprising primary dual exhaust systems and partial engine enclosures, reduce exhaust back pressures by 0.3 to 0.4 in. Hg and add about 2½ percent to the tractor weights. Cooling tests show that engine oil, engine coolant, and air-to-boil temperatures meet manufacturers' specifications. Maintenance studies indicate that about 5 min is required to remove and replace three key access panels.

82-968

Determination of Truck Noise Levels for New Jersey

S.R. Sasor
Div. of Research and Demonstration, New Jersey Dept. of Transportation, Trenton, NJ, Rept. No. NJDOT-81-006-7791, FHWA/NJ-81/006, 121 pp (July 1980)
PB81-247983

Key Words: Trucks, Noise generation

The report describes the analysis of noise data taken for 2 to 6 axle trucks and 2 and 3 axle buses as they travelled on flat, upgrade, and downgrade highways within New Jersey. Reference noise emission levels as a function of speed are presented for the two general classes (medium trucks and buses, and heavy trucks) which were found to represent all of the classes of vehicles which were investigated. Separate emission levels are given for each type of roadway. Overall and octave band emission levels for the two general classes are compared for each of the roadway types. In addition, New Jersey's noise emission levels for trucks are compared to the national average truck emission levels contained in the Federal Highway Administration highway noise prediction method. A statistical examination of New Jersey's noise data is included as well.

82-969

Development of an Indoor Noise Test Procedure for Trucks

W.R. Semrau
General Motors Corp., Warren, MI, SAE Paper No. 810856

Key Words: Trucks, Noise measurement, Measurement techniques

An alternate, indoor, noise test procedure for truck exterior noise is developed in order to overcome the weather problems associated with the presently employed outdoor test method. The feasibility of a reverberation room measurement of sound power level is demonstrated through a series of comparative indoor and outdoor measurements for several vehicles.

82-970

Current and Future Status of Motor Vehicle Noise Regulation in the Province of British Columbia, Canada

D.S. Kennedy
Hartford, Kennedy, Wakefield Ltd., Acoustical Consultants, Vancouver, British Columbia, Canada, SAE Paper No. 810860

Key Words: Motor vehicle noise, Noise measurement, Measurement techniques

Over the past six years, government inspection stations in British Columbia have been regularly conducting indoor vehicle noise measurements in order to enforce motor vehicle noise regulations. The program has worked well logistically but certain improvements in measurement procedures are currently being considered with the intent of making these procedures more consistent with recently developed national and international standards.

82-971

Reduction of Noise on Large Size Pipes by Inserting Acoustic Grilles

L. Franco and G. Ruspa

FIAT Res. Ctr., Orbassano, Turin, Italy, Appl. Acoust., 14 (6), pp 417-437 (Nov-Dec 1981) 16 figs, 5 refs

Key Words: Buses, Noise reduction, Silencers

This paper deals with the problem of silencing relatively large intake pipes by inserting reactive and dissipative absorption sections inside the end of the pipe with a cascade arrangement to form an acoustic grille. Experiments were carried out on various internal configurations of the same type of section for silencing intake pipes. This paper describes the application of an acoustic grille for silencing the intake end of an engine cooling pipe on a FIAT IVECO' bus. Experimental results show a noise attenuation of about 5 db(A) on that specific source.

82-972

The Twelfth Sir Richard Fairey Memorial Lecture: The Annoyance Due to Road Traffic Noise, the Mathematical Modelling of Such Noise and the Sound Proofing of Road Vehicles

C. Lamure

Institut de Recherche des Transports, Centre d'Evaluation et de Recherche des Nuisances et de l'Energie, 69500 Bron, France, J. Sound Vib., 79 (3), pp 351-386 (Dec 8, 1981) 27 figs, 9 tables, 46 refs

Key Words: Traffic noise, Mathematical models, Automobile noise, Noise reduction

The paper is divided into three parts illustrating three directions in traffic noise research. Studies on the effects of noise habitually involve surveys about people living close to highways, and these are discussed in the first part. The second part studies methods of prediction of traffic noise and the last part deals with noise reduction at source.

82-973

Foreign Noise Research in Surface Transportation, 1978-1981

D. Barber and C. Modig

Informatics, Inc., Rockville, MD, Rept. No. EPA-550/9-81-317, 373 pp (May 1981)
PB82-100306

Key Words: Traffic noise, Noise reduction

Information on foreign research projects in surface transportation noise abatement was collected from both individuals and organizations. These contacts were queried on the research they either were conducting or funding and the names and addresses of other surface transportation noise researchers. In total, some 700 researchers were contacted. From these contacts, 294 surface transportation noise research projects were identified.

SHIPS

(Also see Nos. 1031, 1032, 1096)

82-974

Modelling of Ship Dynamics Literature Survey

J. Moes

Natl. Res. Inst. for Oceanology, Stellenbosch, South Africa, Rept. No. CSIR/T/SEA-8014, ISBN-0-7988-1795, 52 pp (Oct 1980)
PB82-108861

Key Words: Ships, Mathematical models, Test models

A survey of modeling techniques for ship dynamics was undertaken. The survey was aimed at mathematical and physical modeling of both free-moving and moored ship conditions. In this report the results of a survey of directly available literature are presented and suitable modeling techniques for the study of ship dynamics at NRIO are recommended.

82-975

Investigation of a Nonlinear Application of the Navy's Dynamic Design Analysis Method for Sound Isolated Equipment

W.W.Webbon

Naval Res. Lab., Washington, DC, Rept. No. NRL-MR-4636, 22 pp (Sept 28, 1981)
AD-A104 413

Key Words: Shipboard equipment response, Underwater explosions, Acoustic insulation

The Navy's dynamic design-analysis method (DDAM) is used to predict the peak forces and the deflections expected in items of equipment on combat ships subjected to underwater-explosion attacks. The DDAM cannot be applied directly to sound-isolated equipment because of the nonlinearity in the mounting. A method of linearizing the nonlinear elements of a structure by iterative analysis is described. The average elements are continuously adjusted during the iterative analysis until convergence occurs by matching peak forces and deflections of the nonlinear elements. Trial analyses on a structure consisting of a pair of beams with four or five nonlinear elements show that the method converges within a reasonable number of iterations.

82-976

Ship Silencing Program

K.A. Tobin

Tracor, Inc., SAE Paper No. 810861

Key Words: Ships, Trucks, Noise reduction

The U.S. Navy has long had a program to quiet ships to improve their combat effectiveness. The trucking industry has various on-going programs to reduce truck noise to meet various regulations, reduce operator fatigue and possible hearing loss, decrease community noise and annoyance, and improve operator recognition of warning signals. Although the two programs are vastly different in their basic motivation, dominant noise sources, frequencies of interest, receiver processing, and sound transmission medium, the methodology should be fundamentally similar. This paper, which reflects the views and experience of the author, describes the overall program, disciplines, and general approach used to quiet ships and, hopefully, will stimulate ideas from those engaged in reducing truck noise.

AIRCRAFT

(Also see Nos. 998, 1093, 1131)

82-977

Aircraft Noise Control Practices Related to Ground Transport Vehicles

R.B. Tate and E.K.O. Langhout

Boeing Commercial Airplane Co., SAE Paper No. 810853

Key Words: Aircraft noise, Noise reduction, Ground vehicles, Air conditioning equipment, Engine noise

Aircraft noise control practices which may have application to ground vehicles are presented. Noise sources, design criteria, prediction methods and test facilities are described. Recent application of aircraft noise control methods in the use of sound insulation, structural damping, air conditioning and engine noise are discussed. The overall technical approach (design process) to solving airplane noise problems is emphasized.

82-978

Helicopter Noise Analysis -- Round Robin Test

E.J. Rickley

Transportation Systems Ctr., Cambridge, MA, Rept. No. TSC-FAA-81-13, FAA-AEE 81-13, 79 pp (Aug 1981)
AD-A103 724

Key Words: Helicopter noise, Testing techniques, Data processing

This report documents the results of an international round robin test on the analysis of helicopter noise. Digital spectral noise data of a 3.5-second simulated helicopter flyover and identical analog test tapes containing helicopter noise data, reference signals, test tones and time code signals were sent to 13 participating organizations. The purpose of the test was to evaluate data reduction systems and procedures; to determine the magnitude of the variability between representative systems and organizations; and to identify potential causes and assist in establishing recommended procedures designed to minimize the variability.

82-979

Investigation of Unsteady Airloads on Wings with Oscillating Control for Active Control Purposes

W. Geissler

Advisory Group for Aerospace Res. and Dev., Neuilly-sur-Seine, France, Rept. No. AGARD-R-699, 19 pp (July 1981) (Presented at AGARD Structures and Materials Panel 52nd Meeting, Cesme, Turkey, April 5-10, 1981)
AD-A103 949

Key Words: Aircraft wings, Aerodynamic loads, Active control

Intensive experimental investigations were carried out on a wing section with oscillating control including a streamlined gap between both wing parts. Steady as well as unsteady pressure distributions have been measured outside and inside the gap region for various incidences, flap angles and frequencies. Comparisons between theory and experiment are discussed in detail and the major influences and effects of viscosity are pointed out. The results lead to special conclusions for the applicability of lifting systems for active control purposes.

82-980

Flight Trial of the Aircraft Fatigue Data Analysis System (AFDAS) Mk 2 Prototype

P.J. Howard

Aeronautical Res. Labs., Melbourne, Australia, Rept. No. ARL/STRUC/NOTE-466, 37 pp (Dec 1980) AD-A105 270

Key Words: Aircraft, Fatigue tests

A prototype version of the Aircraft Fatigue Data Analysis System (AFDAS) has been evaluated in flight trials by a comparison with continuously recorded data. Over a limited period of test the range-mean-pairs count of strain cycles was the same for both sets of data, and the gains calculated for the AFDAS are identical to those deducted from the continuous record.

82-981

Improving the Crashworthiness of General Aviation Aircraft by Crash Injury Investigations

W.R. Kirkham

Civil Aeromedical Inst., Oklahoma City, OK, Rept. No. FAA-AM-81-10, 13 pp (May 1981) AD-A103 316

Key Words: Crash research (aircraft), Crashworthiness

An accident investigative research program has correlated injuries to aircraft occupants with the accident severity and structural changes in the crash. Findings brought to the attention of aircraft manufacturers have led to specific aircraft being made more crashworthy.

82-982

An Improved Prediction Method for Noise Generated by Conventional Profile Coaxial Jets

J.R. Stone, D.E. Groesbeck, and C.L. Zola

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-82712, E-994, 32 pp (1981) (Presented at 7th Aeroacoustics Conf., Palo Alto, CA, Oct 5-7, 1981)

N81-32964

Key Words: Aircraft noise, Noise generation, Jet noise

A semiempirical model for predicting the noise generated by conventional velocity profile jets exhausting from coaxial nozzles is presented and compared with small scale static and simulated flight data. Improvements to the basic circular jet noise prediction are developed which improve the accuracy, especially at high jet velocity and near the jet axis.

82-983

Analysis of Interior Noise-Control Treatments for High-Speed Propeller-Driven Aircraft

J.D. Revell and F.J. Balena

Lockheed-California Co., Burbank, CA, J. Aircraft, 19 (1), pp 31-38 (Jan 1982) 7 figs, 1 table, 15 refs (Presented at the AIAA 6th Aeroacoustics Conf., Hartford, CT, June 4-6, 1980)

Key Words: Aircraft noise, Propeller-induced excitation, Interior noise

An analytical method is described for prediction of the interior noise levels for propeller-driven aircraft, given the exterior noise signature, its harmonic spectrum, and a description of the fuselage sidewall structure and various candidate add-on noise-control elements. The structural response is described by the theory of Koval, but simplified to consider the stiffeners as smeared elements. The incremental transmission loss due to add-on noise-control elements is derived from the Beranek and Work method. Comparisons between experimental data and the theory are presented.

82-984

Interior Noise Control by Fuselage Design for High-Speed Propeller-Driven Aircraft

J.D. Revell, F.J. Balena, and L.R. Koval

Lockheed-California Co., Burbank, CA, J. Aircraft,

systems. Special attention is paid to weight reduction by extensive use of composites such as Kevlar fiber reinforced plastics. Crash resistance, ergonomic configuration optimization, aerodynamic improvements, vibration reduction, specific fuel consumption and noise reduction are discussed.

MISSILES AND SPACECRAFT

82-989

The Dynamics and Control of Large Flexible Space Structures - IV

P.M. Bainum, V.K. Kumar, R. Krishna, and A.S.S.R. Reddy

Dept. of Mech. Engrg., Howard Univ., Washington, DC, Rept. No. NASA-CR-164842, 105 pp (Aug 1981)

N81-32168

Key Words: Spacecraft, Shells, Control systems

The effects of solar radiation pressure as the main environmental disturbance torque were incorporated into the model of the rigid orbiting shallow shell and computer simulation results indicate that within the linear range the rigid modal amplitudes are excited in proportion to the area to mass ratio. The effect of higher order terms in the gravity-gradient torque expressions previously neglected was evaluated and found to be negligible for the size structures under consideration. A graph theory approach was employed for calculating the eigenvalues of a large flexible system by reducing the system (stiffness) matrix to lower ordered submatrices. The related reachability matrix and term rank concepts are used to verify controllability and can be more effective than the alternate numerical rank tests. Control laws were developed for the shape and orientation control of the orbiting flexible shallow shell and numerical results presented.

82-990

Dynamics of a Large Class of Satellites with Deploying Flexible Appendages

K.W. Lips

Ph.D. Thesis, The Univ. of British Columbia, Canada (1980)

Key Words: Spacecraft, Satellites, Beams

A general formulation is presented for the vibrational dynamics of satellites having an arbitrary number, type, and orientation of flexible appendages, each capable of deploying independently. In particular, the case of beam-type appendages deploying from a satellite in an arbitrary orbit is considered. The governing nonlinear, nonautonomous, coupled system equations are not amenable to any closed form solution, hence are integrated numerically using a digital computer. Effect of important system parameters is assessed through illustrative configurations representing a large class of gravity gradient and spinning spacecraft. Rather than accumulation of a large amount of data, the emphasis is on evolution of a generalized and organized methodology for coping with such complex dynamical systems.

MECHANICAL COMPONENTS

ABSORBERS AND ISOLATORS

(Also see No. 1075)

82-991

Design and Development of Variable-Load Energy Absorbers

C.M. Svoboda and J.C. Warrick

Simula, Inc., Tempe, AZ, Rept. No. NADC-80257-60, 58 pp (June 16, 1981)

AD-A103 206

Key Words: Energy absorption, Collision research (automotive)

The objectives of this program were to analyze, design, and test variable-load energy absorber concepts. Such energy absorbers make it possible for the limit load of an energy absorbing seat to correspond to the occupant's weight, thus providing optimum crash protection within a given fixed stroking distance. A prime consideration was retrofittability of the variable-load energy absorbers to seats now equipped with fixed-load energy absorbers. Three concepts were developed and/or tested: a wire-bending mechanism, a tube-constricting mechanism, and a hydraulic energy absorber. Preliminary full-scale working models of the wire-bending mechanism and the tube-constricting mechanisms were built and tested.

82-992

HAWK Launcher Shock Absorber (Part Number 11567877) Final Test Report

J.D. Alston

19 (1), pp 39-45 (Jan 1982) 18 figs, 5 tables, 11 refs (Presented at the AIAA 6th Aeroacoustics Conf., Hartford, CT, June 4-6, 1980)

Key Words: Aircraft, Interior noise, Noise control

An analytic study was performed to define the acoustical treatment weight penalties that are required to provide an interior noise level of 80 dBA in propfan-powered aircraft at Mach 0.8 cruise. The prediction method, described in a companion paper, combines Koval's theory for cylindrical shell noise transmission loss with Beranek and Work's method for multilayered acoustic treatment analyses. Three fuselage diameters are studied which represent commuter, narrow-body, and wide-body aircraft.

82-985

Noise Control Measures in the New Singapore International Airport

R.B.W. Heng

Dept. of Mech. and Prod. Engrg., Natl. Univ. of Singapore, Kent Ridge, Singapore, Appl. Acoust., 14 (6), pp 439-453 (Nov-Dec 1981) 7 figs, 9 tables, 9 refs

Key Words: Aircraft noise, Noise reduction, Airports

Noise control measures incorporated in the passenger terminal building at the new Singapore International Airport at Changi are described. Some of the special steps taken to incorporate the latest acoustics techniques in this airport are reviewed. These include the establishment of norms for various factors such as permissible background noise levels to each of the rooms, offices, arrival and departure halls, etc. Specifications called for include optimum sound absorption and reverberations times, airborne sound insulation for internal and external building partitions and structure-borne sound insulation, as well as a sophisticated sound reinforcement system.

82-986

Characterization, Parameter Estimation, and Aircraft Response Statistics of Atmospheric Turbulence

W.D. Mark

Bolt, Beranek and Newman, Inc., Cambridge, MA, Rept. No. NASA-CR-3463, BBN-4319, 235 pp (Sept 1981)

N81-32139

Key Words: Aircraft, Aerodynamic excitation, Turbulence, Parameter identification technique, Statistical analysis

A nonGaussian three component model of atmospheric turbulence is postulated that accounts for readily observable features of turbulence velocity records, their autocorrelation functions, and their spectra. Methods for computing probability density functions and mean exceedance rates of a generic aircraft response variable are developed using non-Gaussian turbulence characterizations readily extracted from velocity recordings. A maximum likelihood method is developed for optimal estimation of the integral scale and intensity of records possessing von Karman transverse of longitudinal spectra. Formulas for the variances of such parameter estimates are developed. The maximum likelihood and least-square approaches are combined to yield a method for estimating the autocorrelation function parameters of a two component model for turbulence.

82-987

A Study of Methods of Prediction and Measurement of the Transmission of Sound through the Walls of Light Aircraft

B. Forssen, Y.S. Wang, P.K. Raju, and M.J. Crocker School of Mech. Engrg., Purdue Univ., Lafayette, IN, Rept. No. NASA-CR-164712, HL-81-19, 159 pp (Aug 1981)

N81-30904

Key Words: Aircraft, Walls, Sound transmission, Noise prediction, Noise measurement

The acoustic intensity technique was applied to the sound transmission loss of panel structures (single, composite, and stiffened). A theoretical model of sound transmission through a cylindrical shell is presented.

82-988

Helicopter Technologies of the Future

K. Pfleiderer

Messerschmitt-Boelkow-Blohm, GmbH, Munich, Germany, Rept. No. MBB-UD-314/80-OE, 33 pp (Oct 13, 1980)

N81-30125

Key Words: Helicopters, Noise reduction, Vibration control, Fiber composites

An assessment of the future possibilities for the helicopter is presented, within the broad spectrum of all transport

Ground Equipment and Missile Structures Directorate, Army Missile Command Redstone Arsenal, AL, Rept. No. DRSMI/RL-81-8-TR, AD-E950 157, 53 pp (July 1981)
AD-A105 384

Key Words: Shock absorbers, Launchers, Impact tests

This report summarizes the test methods and results of a series of tests to determine compliance of modified Hawk launcher shock absorbers with Technical Data Package requirements. The primary test was a dynamic impact of the shock absorber with a 1000-lb weight traveling at 28 in./sec. The force/time relationship during shock absorber actuation induced by this impact was recorded on an oscillograph and by a digital computer. Correlation of test results was excellent and performance of the shock absorbers was good.

82-993

Ride Simulation of Passive, Active, and Semi-Active Seat Suspensions for Off-Road Vehicles

K.U. Kim
Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 147 pp (1981)
UM 8127618

Key Words: Suspension systems (vehicles), Seats, Off-highway vehicles, Agricultural machinery, Natural frequencies, Damping coefficients

Mathematical models were developed for passive, active, and semi-active suspension systems for off-road vehicle seat suspensions. Each suspension model was combined with a three degree of freedom model of the vehicle operator to formulate models of the ride systems of off-road vehicles. Ride performance of the suspension systems were computer simulated using the ride models at the various natural frequencies and damping ratios of their suspension systems. The input vibrations for simulation of the ride models were obtained by measuring a real time history of acceleration data at the base of the seat suspension of agricultural tractors during the transport and moldboard plowing operations.

82-994

Dynamic Analysis of Ocean Wave Energy Converter with Multiple-Floating Bodies

M. Masubuchi and Y. Shinomiya
Osaka Univ., Faculty of Engrg., Sulta, Osaka, Japan, Bull. JSME, 24 (197), pp 2036-2042 (Nov 1981) 9 figs, 18 refs

Key Words: Water waves, Energy absorption, Energy conversion

Theoretical analysis is presented for the dynamic behavior of a wave energy converter which has oscillating two-dimensional cylinders and absorbs power in an incident sinusoidal wave train. The energy converter is an array of two or more bodies connected by rigid links. By taking into consideration the interaction of waves between the floating bodies, dynamic equations of a floating system with inertial, restoring and damping forces are derived using velocity potentials assuming a linear theory. Rate of energy absorption when each body in the array oscillates in two modes is obtained. It is shown that nearly 100% efficiency is available under the approximate tuning condition when three or four oscillating bodies are used and also that the band width of energy absorption efficiency will be largely widened compared with the conventional single body energy converter.

82-995

Development of Noise Control Technology for Pneumatic Jumbo Drills

D.L. George and N.J. Matteo
Ingersoll-Rand Research Inc., Princeton, NJ, Rept. No. BUMINES-OFR-100-81, 64 pp (Nov 1980)
PB81-237414

Key Words: Drills, Mufflers

The objective of this program was to investigate, design, develop, and demonstrate noise control techniques that could be designed into new jumbo drills. Techniques used in this program were an isolated drill guide, damped acoustical enclosure, standard mufflers, and a specially designed silencer for the air egress of the enclosure. Conventional mufflers were used for the feed and rotational motor exhausts.

82-996

Design Data for Vibration Isolating Mountings for Machinery on Suspended Floors

J.A. Macinante and H. Simmons
CSIRO, Div. of Appl. Physics, Sydney, Australia 2070, Publ. by Instn. of Engineers, Australia, College of Mechanical Engineers, 11 National Circuit, Barton, ACT 2600, 10 pp (Apr 1981) 19 figs, 8 refs

Key Words: Vibration isolators, Machinery vibration, Mountings

The purpose of these design data is to indicate the vertical natural frequency that is desirable for a machine mounting on a suspended floor of a given vertical natural frequency in order to minimize the transmission of vibration of a given frequency from the machine into the structure supporting the floor.

TIRES AND WHEELS

82-997

Application of the Finite Element Method in the Study of Snap Ring Grooves in Rapid Transit Car Wheels

T.M. Rusin

PAF Associates, Inc., Ramsey, NJ, ASME Paper No. 81-WA/RT-11

Key Words: Wheels, High speed transportation systems, Noise reduction, Finite element technique

This paper discusses the finite element method techniques used in the study of stresses in rapid transit 28-in. (0.711-m) car wheels. Particular attention is given to the elastic stresses near the circular groove under the front rim to accommodate a snap ring for wheel noise reduction.

82-998

A Comparison of Some Static and Dynamic Mechanical Properties of 18 x 5.5 and 49 x 17 Type 7 Aircraft Tires as Measured by Three Test Facilities

R.N. Dodge and S.K. Clark

Dept. of Mech. Engrg. and Appl. Mechanics, Univ. of Michigan, Ann Arbor, MI, Rept. No. NASA-CR-165720, 86 pp (July 1981)

N81-30099

Key Words: Aircraft tires, Dynamic tests, Experimental test data

The properties were measured during static, slow rolling, and high-speed tests, and comparisons were made between data as acquired on indoor drum dynamometers and on an outdoor test track. In addition, mechanical properties were also obtained from scale model tires and compared with corresponding properties from full-size tires. While the tests covered a wide range of tire properties, results seem to indicate that speed effects are not large, scale models may be used for obtaining some but not all tire properties, and that predictive equations developed in NASA TR R-64 are still useful in estimating most mechanical properties.

82-999

Foreign Research in Tire Noise

R. English and C. Modig

Informatics, Inc., Rockville, MD, Rept. No. EPA-550/9-81-318, 149 pp (Aug 1980)

PB81-247066

KeyWords: Tires, Noise generation, Noise reduction

The research of fourteen countries is represented in this compilation of current and planned research outside the US in tire noise research and tire noise control technology including both passenger car tires and truck tires. Topics covered include mechanisms of tire noise generation, on-the-road and laboratory measurement methods, influence of tire variables (tread type, aspect ratio, material, bias vs. radial, tread wear, sidewall stiffness), operating variables (pressure, temperature, speed, load), road surface variables (texture depth, surface material, wet vs. dry, grooving), tire screens, studded tires, tradeoffs with other design variables such as safety (traction, skid resistance), and recommendations for further research.

BLADES

82-1000

Vibration Analysis on Bladed Disk Assemblies of Axial-flow Turbines

S. Michimura, A. Nagamatsu, T. Ikeuchi, and M. Shirai

Tokyo Inst. of Tech., 2-12-1 Ohokayama Meguro-ku, Tokyo, Bull. JSME, 24 (197), pp 1988-1993 (Nov 1981) 10 figs, 2 refs

Key Words: Blades, Turbine blades, Disks, Natural frequencies, Mode shapes, Fast Fourier transformation

Vibration characteristics of bladed disk assemblies of axial-flow turbines are experimentally investigated and calculated. The natural frequencies and the natural modes of bladed disk assemblies are detected experimentally using the fast Fourier transformation of the measured impulsive force and the acceleration, and they are calculated by a new cyclic symmetry method. The results of the calculation are in good agreement with those of the experiment, and it becomes clear that this new cyclic symmetry method is effective for analysis of periodically symmetric structures.

82-1001
A Vibration Analysis of a Turbine Blade System Damped by Dry Friction Forces
A. Zmitrowicz
Inst. of Fluid-Flow Machinery, Polish Academy of Sciences, Gdansk, Poland, Intl. J. Mech. Sci., 23 (12), pp 741-761 (1981) 14 figs, 2 tables, 19 refs

Key Words: Blades, Turbine blades, Coulomb friction, Natural frequencies, Mode shapes

A turbine blade system with dry friction between the shroud ring elements is analyzed and results obtained by a finite element method are presented. Friction forces in the interacting surfaces are described in terms of anisotropic dry friction theory. In the examples, frequencies and mode shapes of undamped free vibrations of the system are analyzed. Vibration excitation due to friction and vibration coupling caused by friction anisotropy are described when vibration is initiated by prescribed displacements or velocities.

82-1002
Noninterference Technique for Measurement of Turbine Engine Compressor Blade Stress
P.E. McCarty, J.W. Thompson, Jr., and R.S. Ballard
Sverdrup/ARO, Inc., Arnold Air Force Station, TN, J. Aircraft, 19 (1), pp 65-70 (Jan 1982) 14 figs, 4 refs (Presented at the AIAA 6th Aeroacoustics Conf., Hartford, CT, June 4-6, 1980)

Key Words: Blades, Compressor blades, Vibration measurement, Stress analysis

A noninterference technique for measuring stress in compressor blades of turbine engines is being developed to alleviate disadvantages associated with conventional strain-gage measurement systems. The noninterference technique uses blade-tip deflection measurements and special data-processing algorithms to infer local blade stress. A prototype of the noninterference technique equipped with a nonintegral blade vibration data-processing algorithm has been experimentally validated. The validation consisted of comparing the test results of the prototype noninterference system with those of a conventional strain-gage blade stress data system during an aeromechanical test of a turbine engine. Direct comparisons were made of amplitude and spectral results and real-time monitoring capabilities between the prototype noninterference and strain-gage systems for compressor instability and stall conditions.

BEARINGS

82-1003
Magnetic Bearings
I. Yasuda
Los Alamos Natl. Lab., NM, Rept. No. LA-tr-81-19, 10 pp (1981)
DE81024201

Key Words: Bearings, Magnetic bearings, Vibration damping

The design and operation of a magnetic bearing are disclosed. This invention relates to non-contacting bearings mounted in bodies rotating and high speeds; i.e., to magnetic bearings with concentric cylindrical parts formed on rotating bodies and stationary bodies. A particular construction is disclosed which enhances the dampening effect for suppressing vibrations.

82-1004
Quiet Bearing Surface Characterization
R.A. Jeffries, H. Ravner, and I.L. Singer
Naval Res. Lab., Washington, DC, Rept. No. NRL-4625, 13 pp (Sept 17, 1981)
AD-A104 412

Key Words: Bearings, Surface roughness, Noise generation

Surface chemical and topographical features of bearings which passed or failed Anderometer noise testing were correlated with their noise characteristics. No surface chemical differences existed between noisy or quiet bearings. The former did, however, exhibit bands of circular scratches on polar ends of ball surfaces with an equatorially located narrow frost band consisting of small (2-5 micrometers in diameter) pits of the type associated with contact fatigue. Quiet bearings also possessed frost bands which were always wider and sometimes multiple but did not possess the bands of scratches. The ability of the balls in a noisy bearing to roll freely are believed to be hindered; the resulting increase in contact-Hertz loads and sliding frictional forces result in the generation of noise. Interim solutions to the problem are also discussed.

82-1005
A Pad Perturbation Method for the Dynamic Coefficients of Tilting-Pad Journal Bearings
P.E. Allaire, J.K. Parsell, and L.E. Barrett

Dept. of Mech. and Aerospace Engrg., Univ. of Virginia, Charlottesville, VA 22901, Wear, 72 (1), pp 29-44 (Oct 1, 1981) 13 figs, 14 refs

Key Words: Bearings, Journal bearings, Tilting pad bearings, Perturbation theory

A pad assembly method for analyzing tilting-pad bearings is presented. The method results in the complete coefficient matrix for a tilting-pad bearing; the matrix is independent of the pad inertia, the pitch frequency and the number of degrees of freedom of the pad. A pad assembly method is used because it allows the collection of more bearing data with less computer time than a brute force iterative procedure. The results given show the complete dynamical matrices for a five-pad tilting-pad bearing both including and ignoring the damping effects of the unloaded (top) pads. For a symmetrical tilting-pad bearing the reduced cross-coupling coefficients are zero when the moment of inertia of the pad is ignored.

GEARS

82-1006

Dynamic Response of Single Step Gear Drives (Über das dynamische Verhalten von einstufigen Zahnradgetrieben)

F. Kuculay

Lehrstuhl B f. Mechanik, Technische Universität München, Germany, Fortschritt-Berichte VDI-Zt., Reihe 11 (43) (1981), 120 pp, 31 figs, 9 tables, 72 refs. Summarized in VDI-Z., 123 (21), pp 906, 907 (Nov 1981). Avail: VDI-Verlag GmbH, Postfach 1139, 4000 Dusseldorf 1, Germany. Price 72 DM (In German)

Key Words: Mechanical drives, Gears, Approximation methods, Torsional vibration, Axial vibration

An approximation method which gives an insight into the fundamental dynamic response of a single step gear drive and provides means for calculating the dynamic characteristics, such as natural frequencies, gear deflection, gear force, etc. is presented. The method is based on a mathematical model with eight degrees of freedom and takes into consideration torsional, tilting or axial vibrations.

COUPLINGS

82-1007

Torsional Fatigue Strength of a Shrink Fitted Shaft

T. Hattori, S. Kawai, N. Okamoto, and T. Sonobe

Mech. Engrg. Res. Lab., Hitachi Ltd., Tsuchiura-shi, Ibaragi-ken, Bull. JSME, 24 (197), pp 1893-1900 (Nov 1981) 21 figs, 17 refs

Key Words: Couplings, Shafts, Fatigue life, Torsional excitation

Torsional fatigue strength of several types of shrink fitted shaft couplings is estimated based on the results of stress analysis, in which the changes of frictional coefficient and contact pressure during cyclic loading are taken into account. The estimated strengths are confirmed by torsional fatigue tests.

FASTENERS

(See Nos. 1054, 1081)

LINKAGES

82-1008

Calculation of the Dynamic Stability and Periodic Vibrations of Plane Linkages (Zur Berechnung der Dynamischen Stabilitätsbedingungen und Periodischen Schwingungen Ebener Koppelgetriebe)

N. Van Khang

Lehrstuhl f. Theoretische Mechanik, Polytechnische Hochschule Hanoi, Mécanique Appliquée, 26 (4), pp 565-578 (July/Aug 1981) 2 figs, 1 table, 12 refs (In Geman)

Key Words: Linkages, Multidegree of freedom systems, Periodic response

A relatively simple method for the calculation of dynamic stability and periodic vibrations of plane mechanisms with many degrees of freedom is presented. In the dynamic synthesis of plane linkages with elastic members it is advisable to use nonresonant linkage parameters. For the calculation of the dynamic stability and periodic solution of the equations of motion it is possible to use numerical methods.

CAMS

82-1009

The Analytic Development and Experimental Verification of a Predictive Model of a High-Speed Cam-Follower System

A.P. Pisano

Ph.D. Thesis, Columbia Univ., 290 pp (1981)
UM 8125369

Key Words: Cam followers, Mathematical models

In this research, an experimental and theoretical effort is applied to the development and verification of an accurate, predictive, dynamic model of a high-speed cam-follower system. Basic measurements are made on a current automotive cam-follower system (valve train). The dynamic response of the cam-follower system is measured with a high-speed, computer-controlled data acquisition system. Quantities sampled include position and velocity of the output mass (engine valve), reaction force of the return spring (valve spring), and actuating force applied by the cam (pushrod load). With the aid of the experimental data, an accurate, predictive computer model of the cam-follower system is formulated and verified. This dynamic model contains both lumped parameter and distributed parameter representations of machine elements. It is designed to be simple, yet capable of predicting both the manner of cam-follower system misbehavior and the camshaft speed at which the misbehavior first manifests itself. The response of both the cam-follower system and dynamic model is compared and presented for low-, intermediate-, and high-speed operation. Graphs, as well as spectral power densities, are given for both the experimental and the modeled response at three camshaft speeds. Tabulated experimental results are also provided. The experimental results and the dynamic model predictions are in agreement.

STRUCTURAL COMPONENTS

CABLES

82-1010
On the Dynamics of Taut Mooring Systems

E.R. Jefferys and M.H. Patel
London Centre for Marine Technology, Univ. College London, Torrington Place, London WC1E 7JE, UK, Engrg. Structures, 4 (1), pp 37-43 (Jan 1982) 7 figs, 8 refs

Key Words: Moorings, Off-shore structures, Dynamic structural analysis, Finite element technique

The dynamics of vertical taut tethers for compliant offshore platforms are assessed using three types of dynamic analysis and the resulting models are compared. An analytic linear model is derived as a basis for comparison with a linear modal analysis as well as with both linear and nonlinear finite element models. It is shown that the linear finite element and modal can predict the behavior of the continuous tether with adequate accuracy over the frequency range of interest. The finite element model is subsequently used to study the effect of spatial variation of tether tension due to self-weight and square law damping. The validity of equivalent energy dissipative linearization is investigated.

82-1011
Nonlinear Dynamic Response Analysis Using Conjugate Gradients

H.A. Buchholdt and S. Moossavinejad
School of the Environment, Polytechnic of Central London, Regent St., London W1, UK, Engrg. Structures, 4 (1), pp 44-52 (Jan 1982) 9 figs, 4 tables, 18 refs

Key Words: Cables, Nonlinear response, Conjugate gradient method

A method is given for calculating the dynamic response of pretensioned cable structures as well as pinjointed structural assemblies in general. The theory presented allows for nonlinearity and is based upon minimization of the change in the total dynamic work within a given time increment using the method of conjugate gradients. A numerical example showing the use of the method is given.

82-1012
Nonlinear Dynamic Analysis by Modal Superposition

L.F. Geschwindner, Jr.
Pennsylvania State Univ., University Park, PA, ASCE Struc. Div., 107 (12), pp 2325-2336 (Dec 1981) 8 figs, 2 tables, 8 refs

Key Words: Cables, Nonlinear response, Modal superposition method

A modified modal superposition method is developed and used to evaluate the nonlinear dynamic response of a cable network composed of a linkage of straight members with lumped masses. The method is compared with Newmark's B method for accuracy and the time interval requirements for stability. To show the usefulness of the method a number of parameter studies are presented using the cable network as an example.

82-1013

Static and Dynamic Analysis of Axially Loaded Wire Ropes

G.J. Butson

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 107 pp (1981)

UM 8127559

Key Words: Cables, Longitudinal response, Flexural vibration, Torsional response, Natural frequencies

The static and dynamic behavior of axially loaded wire rope is investigated. The longitudinal, torsional, and transverse displacements are determined for a rope which is initially straight in the reference configuration and loaded by an axial force and twisting moment. The static response of wire rope is analyzed using a recently developed technique in which the individual wires in a rope are examined. Solutions for some initial value problems for suspended wire ropes are determined by means of a Laplace transform with a numerical inversion technique. Solutions for the natural modes of vibration of taut rope are found by an eigenvalue approach.

82-1014

Analytical Study for Fatigue of Highway Bridge Cables

S. Basu and M. Chi

Chi Associates, Inc., Arlington, VA, Rept. No. FHWA/RD-81/090, 184 pp (July 1981)

PB81-245672

Key Words: Cables, Bridges, Fatigue life, Crack propagation, Wind-induced excitation, Vortex shedding

Fatigue behavior of highway bridge cables under wind loading is investigated in this report in a comprehensive analytical manner using methodologies of linear elastic fracture mechanics. The report includes the formulation of deflections and bending stresses of highway bridge cables under wind-induced and vortex shedding vibrations, and the formulation of the fatigue behavior of bridge cables in terms of fatigue crack initiation and fatigue crack propagation in bridge cables and in constituent wires. The report further includes a discussion on the fatigue testing of wires and cables and an extensive outline of recommended research programs on the subject from both analytical and experimental standpoints.

BARS AND RODS

82-1015

Wave Propagation in Non-Homogeneous Thin Elastic Rods Subjected to Time Dependent Stress Impact

M.C. Singh and W. Frydrychowicz

Dept. of Mech. Engrg., The Univ. of Calgary, Calgary, Alberta, Canada, J. Sound Vib., 79 (3), pp 341-350 (Dec 8, 1981) 3 figs, 9 refs

Key Words: Rods, Impact response, Time-dependent excitation, Wave propagation

The problem of wave propagation in a non-homogeneous elastic rod subjected to time dependent stress impact is considered. Similarity transformations are applied to the equation of motion of the rod and its boundary condition. Along with the similarity characteristic relationship on the moving front these are used to obtain the similarity representation as a boundary value problem. A closed form solution of the similarity representation is obtained and, in addition, restrictions on the parameters and relations among them are also obtained. Results for the stress distribution in the rod at a specific time are graphically represented in non-dimensional co-ordinates.

BEAMS

82-1016

Spectral Analysis of Nonlinear Wave Load Effects on Offshore Platforms

R. Sigbjörnsson and M. Mörch

Engrg. Res. Inst., Univ. of Iceland, Reykjavik, Iceland, Engrg. Structures, 4 (1), pp 29-36 (Jan 1982) 10 figs, 2 tables, 15 refs

Key Words: Towers, Off-shore structures, Water waves, Stochastic processes

This paper deals with stochastic theory of nonlinear wave forces emphasizing their effects on the structural response of offshore towers. The analysis of forces and response is limited to second-order statistics expressed in terms of power spectral densities. Numerical examples are included to demonstrate the potential of the theory and to quantify the effects of nonlinear forces on the structural response.

82-1017

Numerical Solution to Beam Vibrations under a Moving Couple

J.J. Wu

Large Caliber Weapon Systems Lab., Army Armament Res. and Dev. Command, Watervliet, NY,

Rept. No. ARLCB-TR-81031, 35 pp (Aug 1981) (Presented at the U.S. Army Numerical Analysis and Computer Conf., Huntsville, AL, Feb 26-27, 1981)
AD-A103 387

Key Words: Beams, Moving loads, Gunfire effects, Finite element technique

The finite element solution formulation in time- and space-coordinates is extended to beam vibrations effected by a moving couple. This problem has direct application to gun motions analysis with an unbalanced moving projectile. The moving load, instead of being a time-dependent Dirac delta function as for the case of a moving concentrated force, is now the derivative of this Dirac delta function. This singular function does not present any difficulty due to the variational process employed. This solution procedure is described together with results of beam motions subjected to a couple moving with various speeds.

82-1018
Random Vibration of Cantilever Shear Beams
D.A. Gasparini, A. Debchaudhury, and G. Gazetas
Case Western Reserve Univ., Cleveland, OH, Earthquake Engrg. Struc. Dynam., 9 (6), pp 599-612 (Nov-Dec 1981) 7 figs, 2 tables, 25 refs

Key Words: Beams, Cantilever beams, Random vibration

The behavior of an inhomogeneous triangular shear beam, whose dynamic properties have only recently been derived analytically, is compared to the behavior of homogeneous triangular and prismatic shear beams. Relative displacement, absolute acceleration, seismic coefficient and shear strain responses to non-stationary random excitation are computed. A state space random vibration formulation is used which is analogous to conventional modal time history analysis. The effects of system damping and excitation frequency content and strength envelopes are studied; in particular, the effects of excitation non-stationarity on RMS responses and on first passage probabilities are captured. Non-stationary probabilities of crossing high thresholds are computed by utilizing the evolutionary RMS responses; no use is made of an equivalent stationary duration for either the excitation or the response.

82-1019
A Completely Deformable Timoshenko Beam Type Slider Crank Mechanism
G.O. Amazigo
Ph.D. Thesis, Rensselaer Polytechnic Inst., 177 pp (1981)
UM 8200456

Key Words: Slider crank mechanism, Beams, Timoshenko theory, Flexural vibration, Rotatory inertia effects, Transverse shear deformation effects

The dynamic response of an elastic slider crank mechanism is investigated. The crank and connecting rod are assumed to deform axially and flexurally. The flexural vibrations include shear deformation and rotatory inertia according to the theory of S.P. Timoshenko. External force is applied to the rigid slider which travels in presence of dynamic friction between two parallel, deformable and/or rigid, guides. R.D. Mindlin and L.E. Goodman's method for time dependent boundary conditions (forced vibrations) is applied at the fixed and pinned connections of the mechanism. All the pinned connections are assumed to be frictionless. One of the advantages of the procedure presented is that it can be applied to, and/or extended to, a more complex linkage.

82-1020
Fatigue of Cold Worked Ribbed Reinforcing Bar - A Fracture Mechanics Approach
A.S. Salah el din and J.M. Lovegrove
Dept. of Civil Engrg., The University, Southampton S09 5NH, UK, Intl. J. Fatigue, 4 (1), pp 15-26 (Jan 1982) 15 figs, 2 tables, 37 refs

Key Words: Beams, Structural members, Reinforced concrete, Fatigue life

A theoretical method for the prediction of fatigue life of structural members containing external stress raisers has been developed. The method is based on a linear elastic fracture mechanics approach to fatigue. The theory has been applied to fatigue of Torbar steel in concrete beams. The required parameters for such application were obtained from fatigue tests on samples and finite element analysis of cracked bars. Comparisons between the theory and experimental data taken from other investigations have shown that the theory predicts a reasonable lower limit fatigue life of Torbar in concrete beams. The theory has also successfully predicted the effect of the minimum stress on the fatigue life of this type of bar.

82-1021
Non-linear Free Vibration Analysis of Stepped Beams under Gravity by Transfer Matrix Method
H. Sato

Kanazawa Univ., 2-40-20, Kodatsuno, Kanazawa, Japan, Bull. JSME, 24 (198), pp 2115-2121 (Dec 1981) 6 figs, 3 refs

Key Words: Beams, Variable cross section, Transfer matrix method, Harmonic balance method

The nonlinear free vibrations of stepped beams under gravity are analyzed using the transfer matrix method. Using the harmonic balance method, in which a constant term and a sinusoidal harmonic term are assumed as time functions, the governing partial differential equation reduces to simultaneous ordinary nonlinear differential equations for the corresponding spatial functions. The transfer matrices are derived from these equations. The numerical results for simply supported and clamped, one-stepped thickness beams with rectangular cross-section are presented and the effects of gravity, the beam geometry, the concentrated mass, and the boundary conditions on the nonlinear vibration characteristics are discussed.

82-1022

Oklahoma W-Beam Roadside Barrier Terminal Section Tests

E.L. Marquis and D. Whitis

Texas Transportation Inst., College Station, TX, Rept. No. RF-4166, FHWA/TX-81RF4166, 95 pp (Apr 1981)

PB81-2[illegible]784

Key Words: Guardrails, Beams, Impact tests

A relatively simple method of modifying the turned-down end guardrail terminal has been developed which will eliminate or greatly minimize the probability of a vehicle ramping and rolling over. The modified design uses a 6 in. x 8 in. timber as the first post, a 12 ft. - 6 in. space where a second 6 in. x 8 in. timber post is placed. Thereafter standard 6 in. x 8 in. posts with 6 in. x 8 in. blockouts are placed on 6 ft. - 3 in. centers. The first eight posts have 2 in. holes drilled in the 8 in. side. The guardrail is not bolted to the first eight posts. With the bolts removed, the rail will be depressed to the ground when the turned-down terminal piece is impacted by a vehicle. This action minimizes or eliminates the undesirable violent vehicle ramp and rollover behavior. In order to hold the rail at the proper height (29 in.) before and during vehicle angle impact along the length of need, backup plates are bolted to the first six posts. Successful crash tests have been conducted to verify this behavior.

82-1023

Crash Testing of a Box Beam Guardrail Terminal Section

E.L. Marquis

Texas Transportation Inst., College Station, TX, Rept. No. RF-3920, FHWA-HRP-ND-1-78-B, 68 pp (Feb 1981)

PB81-238933

Key Words: Guardrails, Box beams, Impact tests

North Dakota uses the type G3 box beam roadside barrier with minor modifications thereto. The box beam was chosen because of its narrow profile and low resistance to wind forces and snow drifts. There is no acceptable narrow profile end treatment, and the North Dakota State Highway Department was seeking a relatively simple and inexpensive treatment which would eliminate or greatly reduce the probability of vehicle ramping or rolling. Testing by the Texas Transportation Institute indicates that an acceptable solution has been developed.

82-1024

Colorado Median Barrier End Treatment Tests

R.G. Robertson and H.E. Ross, Jr.

Texas Transportation Inst., College Station, TX, Rept. No. RR-4179-1F, FHWA/RD-81-S01132, 94 pp (May 1981)

PB81-241523

Key Words: Guardrails, Impact tests

Two median barrier end treatment designs were submitted by the Colorado Department of Highways to the Texas Transportation Institute (TTI). After analysis and evaluation, TTI tested the type 3F end treatment design with four crash tests, modifying the design in the process. The final design was deemed acceptable for use on an experimental basis in areas where W-beam guardrails meet in the middle of divided highways.

CYLINDERS

82-1025

Non-Linear Propagation of Directional Cylindrical Waves

S.G. Kelly and A.H. Nayfeh

Dept. of Engrg. Sci. and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 79 (3), pp 415-428 (Dec 8, 1981) 3 figs, 14 refs

Key Words: Cylinders, Vibrating structures, Submerged structures, Wave propagation

The method of renormalization is used to determine a uniformly valid expansion for the problem of nonlinear waves produced in a fluid by the harmonic pulsations of a finite circular cylinder. For a uniform expansion, both the radial and axial distances need to be strained. The effect of dimensionless quantities upon the acoustic shock-formation distance is examined. The results show that the wave produced consists of a number of groups that propagate without any mutual interaction.

COLUMNS

82-1026

Vibrational Characteristics and Seismic Response Analysis of Column Group in Liquid

K. Fujita

Takasago Tech. Inst., Tech. Headquarters, Mitsubishi Heavy Industries, Ltd., Takasago, Hyogo Pref., 676, Japan, Bull. JSME, 24 (197), pp 1994-2002 (Nov 1981) 25 figs, 5 refs

Key Words: Columns, Submerged structures, Seismic response, Interaction: structure-fluid, Tube arrays

A seismic response analysis method of a hexagonal column group installed in a liquid with narrow clearance between columns, which can be supposed to make a coupled vibration due to the interaction between the columns and the liquid, is shown under the condition of continuity in the flow passage and the velocity potential theory. As a result of the parametric study on the sizes of a column group, their vibrational characteristics become clear, and it is possible to estimate the seismic response characteristics of the column group in a liquid for a great number of columns. Some of the calculated values are compared with experimental ones, and it is found that they coincide closely.

FRAMES AND ARCHES

82-1027

Dynamic Collapse of Frames under Wind Disturbances

K. Morisako, S. Ishida, T. Nakamura, and H. Ishizaki

Dept. of Architecture, Kyoto Tech. Univ., Kyoto, Japan, ASCE J. Struc. Div., 107 (12), pp 2365-2380 (Dec 1981) 11 figs, 1 table, 20 refs

Key Words: Frames, Buildings, Multistory buildings, Wind-induced excitation

A parametric numerical analysis is conducted on strain-hardening multi-story frames subjected to wind disturbances generated by amplifying a recorded fluctuating wind pressure. The effect of spreading and diminishing of the strain-hardening regions has been taken into account in the one dimensional finite element formulation employed here. The dynamic behavior including in particular the dynamic collapse behavior is extensively examined and the details are presented for the first time.

82-1028

Analysis and Control of the Noise of Textile Ring-Spinning Frames

N.D. Stewart

Ph. D. Thesis, North Carolina State Univ. at Raleigh, NC, 186 pp (1981)

UM 8128554

Key Words: Framed structures, Textile looms, Noise generation, Noise reduction

The ring-spinning frame is one of the major sources of occupational noise exposure in the textile industry. A search of the literature produced no systematic investigation of the total spinning-frame noise problem though there had been investigations of some of the machine components. Using the methods of source modification and narrow-band frequency analysis, several frames were investigated to determine the existing noise sources, their frequency characteristics, and their relative importance as related to specific machine design and operating characterisitcs. The most important noise sources were found to be the spindle-bobbin system, the ring-traveller system, and the vacuum-end-collection system. An experimental and analytical study was made of the noise of the spindle-bobbin system with emphasis on the oil-lubricated type spindle. This resulted in the development of an elastomeric mounting which can significantly reduce the noise of these spindles.

MEMBRANES, FILMS, AND WEBS

82-1029

Use of Rayleigh-Ritz Method to Study the Vibration Characteristics of a Non-Homogeneous Membrane

S. De

Ole Engrg. Office (QRS.), Santiniketan - 731235 Birbhum, W. Bengal, India, Mécanique Appliquée, 26 (3), pp 471-474 (May/June 1981) 5 refs

Key Words: Membranes (structural members), Flexural vibration, Rayleigh-Ritz method

A particular case of the transverse vibration of a non-homogeneous circular membrane when the density is a function of the radial distance r is presented. The Rayleigh-Ritz method is used to solve the problem.

PLATES

(Also see Nos. 1109, 1120)

82-1030

Further Developments in Transient and Pseudo-Transient Analysis of Mindlin Plates

A. Pica and E. Hinton
Univ. of Pisa, Italy, Intl. J. Numer. Methods Engrg., 17 (12), pp 1749-1761 (Dec 1981) 11 figs, 5 tables, 11 refs

Key Words: Plates, Mindlin theory, Transient response

Some recent developments are presented on a unified approach to the static and transient dynamic geometrically nonlinear analysis of Mindlin plates with initial imperfections.

82-1031

Sound Radiation from Fluid Loaded Orthogonally Stiffened Plates

B.R. Mace
Inst. Sound Vib. Res., Univ. of Southampton, Southampton SO9 5NH, UK, J. Sound Vib., 79 (3), pp 439-452 (Dec 8, 1981) 3 figs, 12 refs

Key Words: Plates, Stiffened plates, Ships, Fluid-induced excitation, Noise generation

The radiation of sound from infinite fluid loaded plates is examined when the plates are reinforced with two sets of orthogonal line stiffeners. The stiffeners are assumed to be equally spaced and exert only forces on the plate. The response to a convected harmonic pressure is found by using Fourier transforms and is given in terms of the harmonic amplitudes of the stiffener forces. These forces satisfy an infinite set of simultaneous equations to which a numerical solution must be found. An expression for the response to a general excitation is derived and from this the acoustic pressure in the far field is determined with particular reference to point force excitation.

82-1032

The Response of Two Fluid-Coupled Plates to an Incident Pressure Pulse

R.S. Schechter and R.L. Bort
Naval Res. Lab., Washington, DC, Rept. No. NRL-MR-4647, 36 pp (Oct 12, 1981)
AD-A104 801

Key Words: Plates, Fluid-induced excitation, Underwater explosions, Explosion effects, Submarines, Shock waves

The response of two plates coupled by an acoustic fluid to an incident pressure pulse is calculated using flat-plate theory. In addition, a similar calculation is done by a different method, where the interior fluid between the plate is modeled as a lumped parameter system of masses and springs. It is shown that as more masses and springs (fluid elements) are used that this solution approaches the continuous fluid solution. The cases where the second plate is backed by water and air are computed using both methods. Calculations are carried out to better understand the interaction of a shock-wave from an underwater explosion and the sail appendage of a submarine.

82-1033

Secondary States of Vibrating Plates

R.J. Matkowsky, L.J. Putnick, and E.L. Reiss
Argonne Natl. Lab., Argonne, IL, Rept. No. ANL-81-49, 25 pp (Aug 1981)
DE81029961

Key Words: Plates, Rectangular plates, Perturbation theory

A previously developed perturbation method is used to obtain a new class of periodic motions for the nonlinear vibrations of rectangular, elastic plates. The dynamic von Karman plate theory is used in the analysis. The new solutions arise by secondary bifurcation from the periodic solutions that bifurcate from the natural frequencies of free vibrations of the linearized plate theory. The new motions are a linear combination of two modes of the linearized theory.

82-1034

Large Amplitude Free Vibrations of Annular Plates of Varying Thickness

J.N. Reddy and C.L. Huang
Dept. of Engrg. Sci. and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 79 (3), pp 387-396 (Dec 8, 1981) 4 figs, 3 tables, 26 refs

Key Words: Plates, Annular plates, Variable cross section, Vibration analysis

The nonlinear free vibrations of thick, orthotropic annular plates with varying thickness are calculated. The formulation is based on the more general Reissner plate equations as well as the von Karman plate equations for variable thickness annular plates. Numerical results for the ratio of the nonlinear period to the linear period of natural vibration are compared with those existing in the literature.

SHELLS

(Also see Nos. 954, 1120)

82-1035

A Study of the Vibration and Buckling of Welded Rectangular Plates

M.M. Kaldas

Ph.D. Thesis, The Univ. of Western Ontario, Canada (1981)

Key Words: Plates, Rectangular plates, Welded joints, Flexural vibration

A theoretical and experimental study of the effect of weld runs on the flexural vibrational characteristics of the common structural element, the rectangular plate, is described. The theoretical treatment is also utilized to study the reduction of elastic critical buckling strength that might be suffered by welded plates due to welding residual stresses.

82-1036

Non-Linear Propagation of Waves Induced by General Vibrations of Plates

A.H. Nayfeh

Dept. of Engrg. Sci. and Mechanics, Virginia Polytechnic Inst. and State Univ., Blacksburg, VA 24061, J. Sound Vib., 79 (3), pp 429-437 (Dec 8, 1981) 14 refs

Key Words: Plates, Vibrating structures, Wave propagation

First-order uniform expansions for the nor linear propagation of waves induced by general motions of plates are obtained. The method of renormalization is used to determine the nonlinear propagation of two waves and 2N waves in a lossless medium. The strained co-ordinates contain terms that account for the effects of self-interaction and mutual interaction of the waves. The mutual interaction terms are negligible if the induced waves are pulses or periodic functions. The method of multiple scales is used to determine the propagation of two waves in a thermoviscous medium. The result consists of two uncoupled equations that can be reduced to Burgers' equations. They account for the effects of dissipation and self-interaction of the waves but not the effects of mutual interaction. A combination of the methods of renormalization and multiple scales can be used to account for dissipation and all interactions.

82-1037

Hydroelastic Vibrations of a Surface Tension Structure in a Satellite Container

H.F. Bauer

Hochschule der Bundeswehr München, Fachbereich Luft- und Raumfahrtechnik, D-8014 Neubiberg, Germany, Z. Flugwiss., 5 (5), pp 303-313 (1981) 7 figs, 12 refs

(In German)

Key Words: Containers, Fuel tanks, Storage tanks, Fluid-induced excitation, Fluid-filled containers, Satellites

The hydroelastic behavior of an elastic wall across an otherwise rigid satellite fuel container with a free liquid surface is investigated. The coupled frequencies, the pressure distribution at the elastic cross-wall and the liquid force upon the container are determined.

82-1038

Characteristics of Wave Propagation and Energy Distributions in Cylindrical Elastic Shells Filled with Fluid

C.R. Fuller and F.J. Fahy

Inst. Sound Vib. Res., Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-116, 43 pp (Mar 1981)

N81-32560

Key Words: Shells, Cylindrical shells, Fluid-filled containers, Interaction: structure-fluid, Energy transfer

Dispersion curves are presented for a range of parameters and the behavior of individual branches is explained. A nondimensional equation which determines the distribution of vibrational energy between the shell wall and the contained fluid was derived and its variation with frequency and material parameters was studied. The behavior of free

waves is found to depend strongly on the thickness of the shell wall and on the ratio of density of shell material to the density of the contained fluid. Coincidence behavior for propagating and evanescent waves is identified and explained.

82-1039

Axisymmetric Wave Transmission through Wall Thickness Discontinuities in Fluid-Filled Cylindrical Shells

C.R. Fuller

Inst. Sound Vib. Res., Southampton Univ., Southampton, UK, Rept. No. ISVR-TR-117, 24 pp (Mar 1981)

N81-32561

Key Words: Shells, Cylindrical shells, Fluid-filled containers, Interaction: structure-fluid

The free vibration motion of the shell is described by the Donnell-Mushtari equations. Dispersion curves for wave behavior in fluid filled shells are obtained and the values are used in equations resulting from an approximate analysis involving the application of boundary conditions across the system discontinuity. Both continuity of shell and fluid wave impedances are included in the analysis. The presence of the fluid is shown to lower the discontinuity transmission loss at frequencies above the shell ring frequency.

82-1040

On a Spectral Problem of Hydroelasticity

I. Aganović

Dept. of Mathematics, Univ. of Zagreb, Zagreb, Yugoslavia, J. de Mécanique, 20 (3), pp 409-414 (1981) 9 refs

Key Words: Shells, Containers, Fluid-filled containers, Spectrum analysis

Small oscillations of an elastic shell container partially filled with an inviscid incompressible liquid are studied. The problem is reduced to a spectral problem for a linear compact symmetric operator in a certain Hilbert space.

82-1041

Dynamic Analysis of Cylindrical Shell under Hot Spot

K. Shirakawa

Dept. of Mech. Engrg., Univ. of Osaka Prefecture, Mozu Umemachi, Sakai, Osaka, Japan, Z. Flugwiss., 61 (9), pp 421-434 (Sept 1981) 6 figs, 16 refs

Key Words: Shells, Cylindrical shells, Thermal excitation

This paper is concerned with the dynamic analysis of a cylindrical shell subjected to a sudden change of temperature field by a hot spot at an initial state. Applying Dirac's delta function to the hot spot, the solutions are presented for the nonstationary equation of heat conduction for shell. The dynamic, thermoelastic cylindrical shell equation retaining all inertia terms are solved by employing Fourier and Laplace transforms. The solutions for a quasistatic problem enable us to discuss the singularities in thermal displacements and stresses. The importance of the dynamic effects in the practical applications is shown by numerical examples.

82-1042

Forced Vibration of an Isotropic Circular Cylinder Having a Rigid Cylindrical Inclusion

S. Bhaduri and M. Kanoria

Shipur Dinobundhoo Instn. (College), Mowrah, India, Mécanique Appliquée, 26 (3), pp 475-480 (May/June 1981) 8 refs

Key Words: Shells, Cylindrical shells, Inclusion, Discontinuity-containing media, Forced vibration, Laplace transformation

The forced vibrations of an isotropic circular cylinder having a rigid co-axial cylindrical inclusion are considered. Laplace transform technique is employed in solving the problem. The frequency equation for the case of free vibration is also derived.

82-1043

Pulse Transmission in Elastic Exponential and Conical Shells

F. Barez and W. Goldsmith

College of Engrg., Univ. of California, Berkeley, CA 94720, Intl. J. Mech. Sci., 23 (11), pp 661-675 (1981) 10 figs, 2 tables, 18 refs

Key Words: Shells, Conical shells, Pulse excitation, Impact tests

A theoretical and experimental investigation was conducted to ascertain the response of an axisymmetric exponential

shell and of a hollow cone with identical terminal dimensions and lengths, both composed of aluminum, to central longitudinal impact by steel spheres.

82-1044

Stresses in Shell Structures

R.L. Nelson
Engrg. Sci. Div., Central Electricity Res. Labs., Central Electricity Generating Board, Leatherhead KT22 7SE, UK, J. Sound Vib., 79 (3), pp 397-414 (Dec 8, 1981) 21 refs, 3 tables, 14 refs

Key Words: Shells, Cylindrical shells, Hyperbolic parabolic shells, Finite element technique, Mode shapes, Natural frequencies

Stresses obtained for various (thin) shell structures by using two types of doubly curved finite elements are compared with published information. One of the elements – a ring shell element – is designed to analyze axisymmetric structures such as cylinders and hyperboloids. The accuracy and convergence of this element is shown to be excellent. The other element – a quadrilateral shell element – is designed to calculate stresses, mode shapes and frequencies of axisymmetric structures as well as sections of shell structures. The quadrilateral element is more versatile than the ring element. However, it is found that the convergence of the ring element is superior to that of the quadrilateral element. The resonant stresses of a hyperboloidal shell structure are presented.

82-1045

Axisymmetric Vibrations of a Cylindrical Shell with Varying Thickness

K. Suzuki, M. Konno, and S. Takahashi
Yamagata Univ., Yonezawa, Japan, Bull. JSME, 24 (198), pp 2122-2132 (Dec 1981) 17 figs, 14 refs

Key Words: Shells, Cylindrical shells, Variable cross section, Axisymmetric vibrations, Natural frequencies, Mode shapes, Transverse shear deformation effects, Rotatory inertia effects

The axisymmetric vibrations of a cylindrical shell of which the thickness varies in the axial direction is analyzed by using the thin cylindrical shell theory and an improved thick cylindrical shell theory. The equations of vibration are solved exactly by using a series solution. As numerical examples the natural frequencies and the mode shapes of cylindrical shells are obtained with both ends clamped, simply supported and free. Influences of the shear deformation and the rotatory inertia upon natural frequencies and mode shapes are discussed.

82-1046

Flow-Induced Vibration Analysis of Three Mile Island Unit-2 Once-Through Steam Generator Tubes. Volume 1. Final Report

J.R. Johnson, J.C. Brown, C.E. Harris, E.J. McGuinn, and J.C. Simonis
Nuclear Power Generation Div., Babcock and Wilcox Co., Lynchburg, VA, Rept. No. EPRI-NP-1876-V.1 DE81903813

Key Words: Tubes, Boiler tubes, Nuclear power plants, Fluid-induced excitation

Tube responses to flow-induced vibration were measured in the top two spans and the tenth span in the B once-through steam generator at Three Mile Island, Unit 2. This program evaluated the effects of flow-induced vibration of OTSG tubes during steady-state and transient operation. Twenty-three tubes were instrumented with accelerometers and strain gages in tubes located along the open lane, in the bundle, and at the tenth span. Tube displacements, frequencies, dynamic strains, and mode shapes were determined during steady-state and transient operation. Pressure sensors were installed in the OTSG to measure pressure fluctuations and plant parameters, which were recorded for correlation with tube response. Data analysis results indicate that the steady-state tube response increases with increasing reactor power, with the maximum response at the outer perimeter of the generator in the 16th span.

82-1047

Thermally Induced Acoustic Oscillations in a Pipe (2nd Report: Oscillations Induced by Interference of Heat Sources)

H. Madarame
Univ. of Tokyo, 7-3-1 Hongo Bunkyo-ku Tokyo, Japan, Bull. JSME, 24 (198), pp 2147-2153 (Dec 1981) 17 figs, 3 refs

Key Words: Pipes (tubes), Thermal excitation, Acoustic response

Thermally induced acoustic oscillations in a pipe in which two or more heat sources are closely installed have been studied analytically and experimentally. The analytical model used in the first report has been improved to describe the effect of the air current temperature change due to the variation of heat flow rate from the upstream source upon

that from the downstream source. If there is a certain phase relation between the pressure variation and the heating rate, thermal energy is converted to acoustic energy, therefore an oscillation is induced. The condition in which the oscillation grows has been clarified as a function of heat generation rate, stream velocity, distance between the heat sources, etc., which is different from that in the case of a single heat source. Experimental results using nichrome heaters agree well with the calculations.

82-1048

Sound Transmission through a Cylindrical Pipe Wall

A.C. Fagerlund and D.C. Chou

Fisher Controls Co., Marshalltown, IA 50158, J. Engrg. Indus., Trans. ASME, 103 (4), pp 355-360 (Nov 1981) 13 figs, 14 refs

Key Words: Walls, Pipes (tubes), Sound transmission

A theory is developed for predicting the limiting transmission loss of sound through pipe wall. The approach is general to allow an evaluation of the effects of the internal and external fluids as well as the basic physical characteristics of the cylinder. The effects of internal static pressure and the presence of a uniform flow are also discussed. Results of an experimental program are presented which verify the theory for standard commercial pipes.

DUCTS

82-1049

Note on Reflection and Transmission Coefficients for Converging-Diverging Ducts

P.A. Durbin

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-82679, E-964, 10 pp (Sept 1981)
N81-30906

Key Words: Ducts, Sound reflection, Sound transmission

Simple formulas for calculating acoustic reflection and transmission coefficients for converging-diverging ducts are derived; they extend the method of Cho and Ingard to arbitrary, slowly varying ducts. These formulas involve two parameters. The first is a function of duct shape and the second is the ratio of the duct radius downstream of the throat to that upstream of the throat. An extension of the method to include mean flow is made for symmetric ducts.

82-1050

Influence of Exit Impedance on Finite Difference Solutions of Transient Acoustic Mode Propagation in Ducts

K.J. Baumeister

NASA Lewis Res. Ctr., Cleveland, Oh, Rept. No. NASA-TM-82666, E-940, 16 pp (1981)
N81-30905

Key Words: Ducts, Sound waves, Sound propagation

The time-dependent governing acoustic-difference equations and boundary conditions are developed and solved for sound propagation in an axisymmetric (cylindrical) hard-wall duct without flow and with spinning acoustic modes. The analysis begins with a harmonic sound source radiating into a quiescent duct. This explicit iteration method then calculates stepwise in real time to obtain the steady solutions of the acoustic field.

BUILDING COMPONENTS

82-1051

The Seismic Resistant Design of R/C Coupled Structural Walls

A.E. Aktan and V.V. Bertero

Earthquake Engrg. Res. Ctr., Univ. of California, Berkeley, CA, Rept. No. UCB/EERC-81/07, NSF/CEE-81040, 240 pp (June 1981)
PB82-113358

Key Words: Walls, Structural members, Seismic design, Reinforced concrete, Concretes

A survey of existing analytical and experimental work regarding the seismic response of R/C wall and coupled wall-frame systems, as well as relevant documented post-earthquake studies on these systems, are presented in the first part of this report. An assessment of the states of the art and practice regarding the design of building structures incorporating these systems is included. Studies and design and fabrication of the required testing facility necessary for conducting the experimental investigation of seismic behavior of a 1/3-scale model of a 4½-story coupled wall subassemblage belonging to a 15-story prototype structure, are described in the main portion of this report. Analytical studies of the seismic responses of the prototype buildings are summarized briefly.

82-1052

Experimental Study of Active Structural Control

T.T. Soong and G.T. Skinner

Civil Engrg. Dept., State Univ. of New York at Buffalo, Buffalo, NY 14214, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1057-1067 (Dec 1981) 6 figs, 1 table, 10 refs

Key Words: Structural members, Wind-induced excitation, Active vibration control, Wind tunnel tests

Experimental results of a wind tunnel study in which active control was applied to wind-induced motion of a tall structure are presented. The control consisted of a small appendage situated at the top of the structure. The study represents one of the first active structural control experiments performed in a wind tunnel. The results further demonstrate that the concept of active control may indeed offer a feasible solution for wind-induced structural vibrations in the future.

82-1053

Seismic Response of Nonlinear Systems

E. Endebrock and R. Dove

Los Alamos Natl. Lab., NM, Rept. No. LA-8981-MS, 25 pp (1981)

NUREG/CR-2310

Key Words: Structural members, Hysteretic damping, Seismic response

The seismic response of structural elements that behave as softening, hysteretic systems is investigated. A computer analysis is made to determine the relative importance of the various system parameters. Results, in the form of relative displacement and absolute acceleration spectra, are presented for one degree and two degrees of freedom systems.

82-1054

Response of Reinforced Concrete Plate-Column Connections to Dynamic and Static Horizontal Loads

D.G. Morrison

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 590 pp (1981)

UM 8127650

Key Words: Joints (junctions), Concretes, Reinforced concrete, Plates, Columns, Hysteretic damping

The object of the investigation was to study the response of interior reinforced concrete plate-column connections. Eight specimens were tested, 5 statically and 3 dynamically (rate of loading significant). Other experimental variables were reinforcement ratio and the amount of superimposed vertical load. The statically tested specimens provided information on the influence of the change in reinforcement ratio and the amount of superimposed vertical load on the response to horizontal loading. An analysis model (the grid model) was developed to help interpret the results from the statically tested specimens. The dynamically tested specimens were used to obtain data on the response of the specimens, the observed hysteresis and calculated damping.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

(Also see Nos. 1126, 1129)

82-1055

Variability of Acoustic Transmissions in a Shallow Water Area

E. Sevaldsen

SACLANT ASW Research Centre, La Spezia, Italy, Rept. No. SACLANTCEN-SR-46, 52 pp (May 1, 1981)

AD-A103 278

Key Words: Underwater sound

A series of experiments on the variability of acoustic transmissions in a shallow-water area is described. The variables considered have been time (short period and seasons), frequency of transmission (1 to 6 kHz), and space (location and depth of source, depth of receiver). The variability has been studied mainly in terms of transmission-loss fluctuations and spreading in frequency and delay of phase-coherent pulse signals.

82-1056

Acoustic Intensity Measurements of Transient Noise Sources

F.J. Fahy and S.J. Elliott

Inst. Sound Vib. Res., Univ. of Southampton, S09

5NH, UK, Noise Control Engrg., 17 (3), pp 120-125 (Nov-Dec 1981) 9 figs, 7 refs

Key Words: Sound measurement, Transient sound

The principles and problems of measuring transient sound energy flux density using the two-microphone technique are outlined. Examples are presented of intensity-time histories and radiated energy flux spectra, measured in the sound field generated by a drop forge situated in a reverberant enclosure. The results indicate the transition between the non-diffuse initial field and the onset of a diffuse reverberant field at the measurement position.

82-1057

Noise Characteristics of a Pulsed Jet

R.J. Hooker and R.H. Rumble
Univ. of Queensland, Dept. of Mech. Engrg., St. Lucia, Queensland, Australia 4067, Noise Control Engrg., 17 (3), pp 113-119 (Nov-Dec 1981) 8 figs, 2 tables, 10 refs

Key Words: Jet noise, Pulse excitation

The exhaust flow of many gas-powered machines consists of a series of distinct pulses. This non-steady jet flow has been studied experimentally by use of a simple pulse jet generator in which a rotating valve interrupts a flow of air. The valve porting was chosen to simulate the exhaust cycle of a pneumatic percussive drill and the noise produced by the generator is similar to that of a drill exhaust. The sound field around the pulsed jet has been measured in free-field conditions. Results are presented showing sound levels, spectra and directivity patterns for a range of supply pressures.

82-1058

Pressure Dependence of Jet Noise and Silencing of Blow-Offs

D.-y. Maa and P.-z. Li
Inst. of Acoustics, Academia Sinica, Peking, People's Republic of China, Noise Control Engrg., 17 (3), pp 104-112 (Nov-Dec 1981) 16 figs, 13 refs

Key Words: Jet noise, Noise reduction, Noise prediction

In order to facilitate the prediction of the sound field produced aerodynamically, empirical expressions are found for sound pressure levels and A-weighted sound levels of cold-air jet noise, which include both turbulent and shock-cell noise, in terms of the stagnation pressure and size of the nozzle. The expressions hold for an over-pressure ratio from about 0.01 to 100, within a range of 2 dB. The shock-cell noise is found to be influential only in a limited range of over-pressures, roughly from 1 to 7 atmospheres.

82-1059

Acoustic Performance of Inlet Suppressors on an Engine Generating a Single Mode

L.J. Heidelberg, E.J. Rice, and L. Homyak
NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-82697, E-980, 24 pp (1981) (Presented at the 7th Aeroacoustics Conf., Palo Alto, CA, Oct 5-7, 1981)
N81-32968

Key Words: Linings, Engine noise, Noise reduction

Three single degree of freedom liners with different open area ratio face sheets were designed for a single spinning mode in order to evaluate an inlet suppressor design method based on mode cutoff ratio. This mode was generated by placing 41 rods in front of the 28 blade fan of a JT15D turbofan engine. At the liner design this near cutoff mode has a theoretical maximum attenuation of nearly 200 dB per L/D.

82-1060

Propagation of Sound through the Earth's Atmosphere 1: Measurement of Sound Absorption in the Air: 2: Measurement of Ground Impedance

R.W. Meridith and J. Becher
Dept. of Physics, Old Dominion Univ., Norfolk, VA, Rept. No. NASA-CR-164834, PTR-81-4-REV, 22 pp (Sept 1981)
N81-32967

Key Words: Sound propagation, Acoustic absorption, Acoustic impedance, Measurement techniques

Parts were fabricated for the acoustic ground impedance meter and the instrument was tested. A rubber hose was used to connect the resonator neck to the chamber in order to suppress vibration from the volume velocity source which caused chatter. An analog to digital converter was successfully hardwired to the computer detection system. The cooling system for the resonant tube was modified to use liquid nitrogen cooling. This produced the required tempera-

ture for the tube, but the temperature gradients within each of the four tube sections reached unacceptable levels. Final measurements of the deexcitation of nitrogren by water vapor indicate that the responsible physical process is not the direct vibration-translation energy transfer, but is a vibration-vibration energy transfer.

82-1061

Purification Plants: Noise Aspects and Provisions

W.M. Schuller

Akoestisch Adviesbureau Peutz & Associes B.V., Nijmegen and The Hague, The Netherlands, Appl. Acoust., 14 (6), pp 403-416 (Nov-Dec 1981) 20 figs, 2 tables, 2 refs

Key Words: Industrial noise, Noise reduction

Noise in and around purification plants will be dealt with in this paper. After studying potential noise sources in order to obtain a prognosis of the sound pressure levels with the help of empirical formulae for the specific noise sources encountered in purification plants – for example, cone aerators, bubble aeration, overflow weirs and Archimedial screws – the possibilities of making additional provisions for the reduction of noise from these sources will be discussed. New developments in the determination of the sound power level of splashing water produced by cone aerators and of the sound absorption of splashing water are described. Practical noise control provisions, resultant noise reduction and costs are discussed.

82-1062

Turbomachinery Noise Studies of the Airesearch QCGAT Engine with Inflow Control

J.G. Mcardle, L. Homyak, and D.D. Chrulski

NASA Lewis Res. Ctr., Cleveland, OH, Rept. No. NASA-TM-82694, E-977, 26 pp (1981) (Presented at the 7th Aeroacoustic Conf., Palo Alto, CA, Oct 5-7, 1981; Sponsored by AIAA)

N81-31957

Key Words: Turbomachinery noise, Noise reduction

The AiResearch Quiet Clean General Aviation Turbofan engine was tested on an outdoor test stand to compare the acoustic performance of two inflow control devices (ICD's) of similar design, and three inlet lips of different external shape. Only small performance differences were found. Far-field directivity patterns calculated by applicable existing analyses were compared with the measured tone and broadband patterns. The comparisons showed that the analytical expressions used predict many directivity pattern features and trends, but can deviate in shape from the measured patterns under certain engine operating conditions. Some patterns showed lobes from modes attributable to rotor/engine strut interaction sources.

SHOCK EXCITATION

82-1063

The Influence of Seismic Source Directivity on Strong Ground Motions

J.P. Singh

Ph.D. Thesis, Univ. of California, Berkeley, CA, 195 pp (1981)

UM 8200276

Key Words: Dams, Nuclear power plants, Seismic excitation

Because of the need to site critical facilities such as dams, nuclear power plants, etc. in the near field region of active faults, an increasing emphasis has been placed on developing reasonable estimates of ground motion characteristics for design in the near field. The influence of the source mechanism and travel path in establishing these ground motion characteristics has been, in general, estimated through the use of only two parameters, i.e., magnitude for source and distance for travel path. The use of these parameters to represent the complex source and travel path problem differs considerably from the attention devoted to such well studied factors as different local soil conditions. To develop a basis for explaining the apparent inconsistencies of recorded data and to develop information for estimating ground motion in the near field, it is important to develop a physical understanding of the source and travel path characteristics. This study examines the seismic source directivity facet of the source problem and evaluates its significance in assessment and quantification of earthquake ground motions in the near field.

82-1064

Dynamic Measurement of Poisson's Ratio in Granular Materials at 0.2 to 0.8 GPa

C.W. Olsen

Lawrence Livermore Natl. Lab., CA, Rept. No. UCRL-85539, 20 pp (July 1981)

DE81027559

Key Words: Granular materials, Underground explosions, Shock wave propagation, Poisson's ratio

Modeling the response of the material surrounding an underground explosion requires a detailed knowledge of the material properties and its equation-of-state. The material is usually porous, granular material whose properties are not well known. We have developed a technique for measurement of Poisson's ratio for shock-loaded, granular material. All tests have been conducted in a 63.5 mm diameter gas-gun. A fixed knife-edge of three thicknesses of 0.3 mm stainless steel was instrumented with carbon stress gauges and Constantan strain gauges. A 0.13 mm stainless steel cover provided gauge protection. The knife-edge was mounted in the target material, dry sand, so as to measure the transverse pressure. By knowing the impact pressure and the orthogonal pressure, Poisson's ratio can be determined.

82-1065
Electronic Measurement of Airblast Overpressure
Army Test and Evaluation Command, Aberdeen Proving Ground, MD, Rept. No. TOP-4-2-822, 28 pp (Sept 28, 1981)
AD-A105 379

Key Words: Explosion effects, Blast loads, Measurement techniques

This report describes methods of measuring airblast overpressures above 170 dB (1 psi or 6.9 kPa), resulting from detonation of explosives or firing of guns. It describes the direct-pressure method and the shock wave velocity method for measuring airblast. It also includes techniques for calibrating transducers used for measuring airblast overpressure, and describes overpressure-measuring devices.

82-1066
The Containment of Blast Effects from the Detonation of Small High Explosive Charges
W.F. Jackson
Ballistic Res. Lab., Army Armament Res. and Dev. Command, Aberdeen Proving Ground, MD, Rept. No. ARBRL-MR-03124, 25 pp (Aug 1981)
AD-A105 164

Key Words: Blast effects, Explosion containment

A spherical containment device to be used for the safe transportation of high explosives was evaluated for its ability to suppress blast effects from internal explosive detonations of charge weights extending to 483 gms (17.03 oz.) of 50/50 pentolite explosive. The device consisted of a steel sphere with a specially designed port to permit the placement of high explosive material inside. In a series of tests, charges of different weights were detonated inside the device. Overpressure measurements were recorded at 61 cm. from the outside surface and pressure measurements were made on the interior. The strain experienced by the sphere was measured on the outside surface. The study demonstrated that the design criteria has been met since the device was capable of containing the explosive gases and restricting the exterior overpressure below the threshold for human ear drum rupture.

82-1067
Pulse Control of Single Degree-of-Freedom System
F.E. Udwadia and S. Tabaie
Univ. of Southern California, Los Angeles, CA, ASCE J. Engrg. Mechanics Div., 107 (6), pp 997-1009 (Dec 1981) 8 figs, 10 refs

Key Words: Single degree of freedom systems, Vibration control, Active vibration control

The feasibility of using open-loop on-line adaptive pulse control to limit the vibrations of structural and mechanical systems, which are subjected to dynamic load environments, is investigated. The control algorithm is developed for a system modeled as a single degree of freedom oscillator. The technique while capable of adequate control for both linear and nonlinear systems subjected to stochastic loads, requires, unlike optimal control theoretic methods, a minimal amount of online computations to be performed. Results for linear time-invariant and time-variant as well as nonlinear systems are presented.

82-1068
Pulse Control of Structural and Mechanical Systems
F.E. Udwadia and S. Tabaie
Univ. of Southern California, Los Angeles, CA, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1011-1028 (Dec 1981) 9 figs, 1 table, 7 refs

Key Words: Multidegree of freedom systems, Dynamic response, Base excitation, Seismic excitation, Response limiting, Seismic design

The feasibility of using open-loop adaptive on-line pulse control is considered for limiting the response of large linear multi-degree-of-freedom systems subjected to general dynamic loading environments. Pulses of short durations are used to control the system when the system response exceeds a given threshold level. The pulse magnitudes are

obtained in closed form, leading to large computational efficiencies when compared with optimal control theoretic methods. The technique is illustrated for a structural system subjected to earthquake-like base excitations.

82-1069
Shock Associated Noise Reduction from Inverted-Velocity-Profile Coannular Jets

H.K. Tanna, C.K.W. Tam, and W.H. Brown
Lockheed-Georgia Co., Marietta, GA, Rept. No. NASA-CR-3454, LG81ER0162, 161 pp (Aug 1981) N81-30908

Key Words: Shock waves, Noise reduction, Jet noise

Acoustic measurements show that the shock noise from the outer stream is virtually eliminated when the inner stream is operated at a Mach number just above unity, regardless of all the other jet operating conditions. At this optimum condition, the coannular jet provides the maximum noise reduction relative to the equivalent single jet. The shock noise reduction can be achieved at inverted as well as normal-velocity-profile conditions, provided the coannular jet is operated with the inner stream just slightly supersonic. Analytical models for the shock structure and shock noise are developed and indicate that a drastic change in the outer stream shock cell structure occurs when the inner stream increases its velocity from subsonic to supersonic. At this point, the almost periodic shock cell structure of the outer stream nearly completely disappears; the noise radiated is minimum. Theoretically derived formulae for the peak frequencies and intensity scaling of shock associated noise are compared with the measured results, and good agreement is found for both subsonic and supersonic inner jet flows.

82-1070
Transonic Shock - Turbulent Boundary Layer Interaction and Incipient Separation on Curved Surfaces

G.R. Inger
Dept. of Aerospace Engrg Sciences, Colorado Univ. at Boulder, CO, 24 pp (June 1981) (Presented at the 14th AIAA Fluid and Plasma Dynamics Conference, June 23-25, 1981, Palo Alto, CA)
AD-A103 307

Key Words: Shock wave propagation

A detailed analysis is made of weak normal shock-turbulent boundary layer interactions on longitudinally-curved surfaces for the case of non-separating steady 2-D flow. It is shown that the interactive viscous displacement effect on the local outer inviscid transonic flow eliminates the well-known singularity pertaining to a curved wall. The inner interaction solution within the boundary layer reveals that curvature moderately influences the interaction through the turbulent eddy viscosity. A non-asymptotic triple-deck solution valid over a wide range of practical Reynolds numbers is given which incorporates this effect, and example numerical results are presented and verified by comparison with experimental data. Small amounts of curvature are found to moderately spread out and thicken the interaction zone while also delaying slightly the onset of any incipient separation that occurs under the shock.

82-1071
Seismic Risk Analysis of Structural Systems

A.D. Kiureghian
Civil Engrg. Dept., Univ. of California at Berkeley, Berkeley, CA, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1133-1153 (Dec 1981) 11 figs, 2 tables, 13 refs

Key Words: Earthquake damage, Damage prediction, Reliability

A methodology for reliability assessment of structural systems subjected to seismic risk is developed. Based on modern concepts of structural reliability theory, structural safety against earthquakes is described through a performance function of ground motion variables. A multivariate risk analysis is then performed to compute the failure probability. The method can be applied to any type of structural system for which a performance function can be formulated. A specific application to linear structures using the response spectrum of ground motion is developed where the performance function is shown to be of quadratic form in terms of spectral ordinates. This application is illustrated through a numerical example for a two-degree-of-freedom structure with multiple failure modes. The example is also used to examine the accuracy of a conventional method that uses marginal probabilities to approximate a joint distribution.

VIBRATION EXCITATION

82-1072
Stall Flutter Experiment in a Transonic Oscillating Linear Cascade

D.R. Boldman, A.E. Buggele, and G.M. Michalson
NASA Lewis Res. Ctr., Cleveland, OH, Rept. No.

NASA-TM-82655, E-918, 19 pp (1981) (Presented at Annual Mtg. of ASME, Washington, DC, Nov 15-20, 1981)
N81-31126

Key Words: Airfoils, Cascades, Flutter

Two dimensional biconvex airfoils were oscillated at reduced frequencies up to 0.5 based on semi-chord and a free stream Mach number of 0.80 to simulate transonic stall flutter in rotors. Steady-state periodicity was confirmed through end-wall pressure measurements, exit flow traverses, and flow visualization. The initial flow visualization results from flutter tests indicated that the oscillating shock on the airfoils lagged the airfoil motion by as much as 80 deg. These initial data exhibited an appreciable amount of scatter; however, a linear fit of the results indicated that the greatest shock phase lag occurred at a positive interblade phase angle. Photographs of the steady-state and unsteady flow fields reveal some of the features of the lambda shock wave on the suction surface of the airfoils.

82-1073
Random Response to Flow-Induced Forces
T.D. Spanos and T.W. Chen
Engrg. Mechanics Dept., Univ. of Texas, Austin, TX, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1173-1190 (Dec 1981) 9 figs, 1 table, 17 refs

Key Words: Flow-induced excitation, Random response

The response statistics of a linear structure subjected to excitation induced by a random flow with a non zero-mean velocity is examined. The technique of statistical linearization is applied on the nonlinear equation of motion of the structure. Approximate solutions for the structural response statistics are obtained. The Pierson-Moskowite is used to describe the energy versus frequency distribution of the randomly fluctuating component of the fluid motions. Results of several studies regarding parameters such as the fluid density and the structural stiffness are presented. The accuracy and efficiency of the analytical approach is assessed by comparison with data obtained by Monte Carlo simulations of the random structural response.

MECHANICAL PROPERTIES

DAMPING
(Also see No. 1108)

82-1074
Broad Spectrum Vibration Damper Assembly Fixed Stator Vanes of Axial Flow Compressor
C.B. Jones
Dept. of the Air Force, Washington, DC, U.S. PATENT-4 285 633, 7 pp (Aug 25, 1981)

Key Words: Vibration dampers, Compressors

The patent describes a method whereby undesirable vibrations of stator airfoil vanes circumferentially disposed in annular rows, and fixed at their ends by a sectored outer shroud and a sectored inner shroud, in an axial flow compressor of a gas turbine engine. They are damped by a damper assembly that is fitted into, and is frictionally engaged, in the sectored inner shroud which, in turn, is segmented to assist in this damping. The damper assembly includes: a metal seal strip member having indentations; a metal sine wave-shaped damper and spring member that is complementary to, and is engaged with, the seal strip member; and, a honeycomb member affixed to the bottom surface of the seal strip member. The vibrations cause movement of the shroud segments which, in turn, cause rubbing contact; and, the resulting friction heat energy is conducted through the metal components of the damper assembly to the thermal sink that is the through-flowing air in the compressor.

82-1075
An Investigation of the Vibration Isolator Equipped with Dual Dynamic Dampers as a Damping Element (1st Report, Optimum Adjustment Condition for Dual Dynamic Dampers)
K. Seto and K. Iwanami
Dept. of Mech. Engrg., Natl. Defense Academy, Yokosuka, Kanagawa, Japan, Bull. JSME, 24 (197), pp 2013-2019 (Nov 1981) 17 figs, 5 refs

Key Words: Vibration isolators, Vibration damping

In order to improve the isolation performance of conventional vibration isolators, this paper proposes an application of dual dynamic dampers in place of viscous damping elements in the vibration isolator. The dual dynamic dampers equivalent in total size to a single one can be applied in a limited space. To reduce effectively the transmissibility at resonance peak, the optimum adjustment condition of the dual dynamic dampers is investigated theoretically and the design data of them are presented in graphical form. Subsequently, the effect of the dual dynamic dampers to control the resonance peak is shown to be greater than that of a single dynamic damper. The effectiveness of the vibration isolator equipped with the dual dynamic dampers indicated by the theoretical analysis is demonstrated experimentally by using a compact variable-stiffness type dynamic damper with magnetic damping.

FATIGUE

(Also see Nos. 931, 959, 960, 980, 1084)

82-1076

Stresses in Drill Steels Leading to Fatigue Failure

J.J. Marais

Ph.D. Thesis, Univ. of Pretoria, South Africa (1980)

Key Words: Drills, Steel, Fatigue life

In mechanized development drilling in gold-mines, the premature failure of drill steels is a disturbing factor. The drill steels fail mainly due to fatigue and their current cost is about R120 each. The unexpected short life of a drill steel has an important bearing on the overall cost of mechanized development work. These drill steels are either imported in the processed form or the blanks are imported and locally processed. Spending of relatively large sums of money overseas is also involved. The current investigation involved the adaption of existing theory and the development of fresh approaches, based on the Euler strut theory, to predict stress levels in the drill steel. In this approach all relevant drilling parameters are taken into account. It is shown that three stresses are important for the fatigue life of a drill steel, i.e., rotational bending stress, dilatational and flexural stress waves.

82-1077

Standard Method of Test for Constant-Load-Amplitude Fatigue Crack Growth Rates in Marine Environments

T.W. Crooker, F.D. Bogar, and G.R. Yoder

Naval Res. Lab., Washington, DC, Rept. No. NRL-MR-4594, 25 pp (Aug 6, 1981)
AD-A103 195

Key Words: Crack propagation, Fatigue tests, Metals, Underwater structures

The determination of fatigue crack growth rates in marine environments is known to be influenced by numerous experimental factors. Therefore, it is necessary to formulate a standard method of test to assure uniformity of test results. This report describes recommended procedures for the measurement of fatigue crack growth rates for metallic materials tested in marine corrosion environments.

82-1078

Bi-MODAL Fatigue Curves

R.G. Lambert

Aerospace Electronic Systems Dept., General Electric Co., Utica, NY, 25 pp (May 1980)
AD-A103 210

Key Words: Fatigue tests, Structural elements

The objective of screening tests is to detect workmanship defects in electronic 'black boxes' prior to delivery to the customer. Such tests typically involve subjecting the units under test (UUT) to temperature cycling and random vibration tests. All of the structural elements within the UUT (e.g. the individual piece parts, solder joints, leads wires, support structures) cumulate fatigue damage during the screening test and subsequently during the intended service environment. The cumulative fatigue damage may range from very little to very large depending upon the individual stress levels and number of stress cycles experienced by each structural element. This study will develop the approach to predicting fatigue life and mechanical reliability for such structural elements. The results of this study would be used to analyze the mechanical reliability of all the structural elements in the UUT as a whole.

82-1079

The Influence of Minor Cycles on Low Cycle Fatigue Crack Propagation

B.E. Powell, T.V. Duggan, and R. Jeal

Mech. Behavior of Materials Lab., Portsmouth Polytechnic, Anglesea Rd., Portsmouth, Hants P01 3DJ, UK, Intl. J. Fatigue, 4 (1), pp 4-14 (Jan 1982) 14 figs, 6 tables, 22 refs

Key Words: Fatigue life, Gas turbines, Compressor blades, Blades

The influence of relatively high frequency low amplitude vibrations superimposed on higher amplitude low frequency major cycles is studied, for titanium alloy (Ti-6A1-4V). It is concluded that the major cycles causing low cycle fatigue are of greatest significance during crack formation and for fatigue crack growth until the minor cycles are triggered by exceeding the appropriate fatigue threshold level. Beyond this point, for realistic numbers of minor cycles, as might occur in gas turbine and compressor blades and discs, the damage caused by high cycle fatigue dominates. For all practical purposes, once minor cycles activity is triggered, the component should be considered to have used up its useful life.

82-1080

Mode III Fatigue Crack Propagation Rates in 6061-T6 Aluminium

R.P. Wright and R.A. Queeney

Dept. of Engrg. Science and Mechanics, Pennsylvania State Univ., 126 Hammond Bldg., University Park, PA 16802, Intl. J. Fatigue, 4 (1), pp 27-30 (Jan 1982) 4 figs, 6 refs

Key Words: Fatigue (materials), Aluminum, Crack propagation

Fatigue crack growth rates were studied in type 6061-T6 aluminium alloy. Unlike the preponderence of previous studies, the present observations were carried out on cracks driven by a Mode III, or antiplane shear, type of loading. The observed crack growth rates were precisely correlated with the Mode III stress intensity factor range, ΔK_{III}. A simple power growth rate law, similar to that which predicts the growth rates of the more common Mode I driven crack, relates the incremental extension of the fatigue crack per cycle of loading to the stress intensity factor range. Fractographic examination of the fatigue crack surfaces indicated that the cracks propagated transgranularly, and did not seek out principal tensile stress planes, or Mode I growth habits.

82-1081

Measuring Fatigue Cracks in Fillet Welded Joints

I.F.C. Smith and R.A. Smith

Engrg. Dept., Cambridge Univ., Trumpington St., Cambridge CB2 1PZ, UK, Intl. J. Fatigue, 4 (1), pp 41-45 (Jan 1982) 6 figs, 1 table, 12 refs

Key Words: Joints (junctions), Welded joints, Fatigue (materials), Measurement techniques

Accurate measurement of short ($<$ 1 mm depth) elliptical fatigue cracks that grow from the toes of fillet welds has proved to be an obstacle to the application of fracture mechanics principles to welding fatigue. This paper reports a DC potential drop technique which allows continuous measurement of the depth of such elliptical cracks. A delicate compromise between sensitivity and accuracy, combined with superior electrical stability displayed by the measurement apparatus, has allowed detection of: 1 - crack growth less than 0.01 mm and; 2 - crack growth rates less than 10^{-7} mm/cycle for cracks less than 1 mm deep. Preliminary results have indicated the relative importance of stress ratio, defect size and material variation on the growth of these short elliptical cracks. When the weld toe is subject to high stress ratios the phenomenon may be considered propagation dominated whereas low stress levels increase the influence of threshold and initiation mechanisms.

82-1082

Dynamic Fracture in Viscoelastic Solids

K.S. Kim and W.G. Knauss

Graduate Aeronautical Labs., California Inst. of Tech., Pasadena, CA, Rept. No. GALCIT-SM-81-7, 87 pp (July 1981)
AD-A104 687

Key Words: Viscoelastic media, Fracture properties, Crack propagation

Dynamic crack propagation in viscoelastic media is studied experimentally with a polyester known as Homalite 100 and a polyurethane known as Solithane 113 at various temperatures. Employing the optical method of caustics, high speed photography is used to determine the variation of the stress intensity factor and the velocity of a running crack initiated and driven by the dynamic step loading on the faces of an initial semi-infinite track in an infinite medium. The loading condition is simulated experimentally with the technique introduced by Smith and Knauss. In this work an application of the method of caustics is extended for the determination of the time dependent stress intensity factor of a running crack in a viscoelastic material. Also, the viscoelastic effects on the initiation of a running crack, the variation of the stress intensity factor, the speed of the crack and the branching of the running crack are discussed. In addition, a mechanism of branching is proposed based on the study of the fracture surfaces.

ELASTICITY AND PLASTICITY

82-1083

Dynamic Deformation and Fracture of Plain and Filled Elastomers

Y.M. Gupta and W.J. Murri

SRI International, Menlo Park, CA, 13 pp (Sept 1981)
AD-A104 105

Key Words: Elastomers, Impact tests, Dynamic properties

To quantify the high strain-rate mechanical response of plain Solithane, compression, shear, and tension experiments were performed under impact loading (microsecond time scales). Compression and tension measurements were carried out for filled Solithane containing 56.5 wt% of glass beads. The results show that the compression response (uniaxial strain) of plain Solithane is dominated by the mean stress-volume relation. The bulk modulus under impact loading is considerably higher than that determined from static measurements in the glassy state. The filled Solithane compression response can be approximated by a simple mixture theory using the Hugoniots of plain Solithane and glass.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

82-1084
An On-Board Microprocessor-Based Data Processor/ Recorder
H.C. Johnson
Electro/General Corp., Minnetonka, MN, SAE Paper No. 810903

Key Words: Measuring instrumentation, Data processing, Fatigue life

The advent of microelectronics, and specifically the microcomputer, has opened up field data collection to include long-term untended applications not previously possible. This paper touches upon two of several field data collection possibilities -- load data analysis and fatigue life estimation -- and describes typical uses for each.

82-1085
Noise Measurement Equipment Accessories
J.J. Chambers and W. Bowlby
Demonstration Projects Div., Federal Highway Admn., Arlington, VA, Rept. No. FHWA-DP-45-3, 30 pp (May 1980)
PB82-117664

Key Words: Noise measurement, Measuring instruments

This report gives material lists and instructions to construct the following accessories for environmental noise measurement equipment: extendable tripod, microphone preamplifier holder for extendable tripod and normal tripod; cable reel with built-in socket; and flashing timer.

82-1086
Low Distortion Oscillator
E.M. Fisher
Dept. of the Army, Washington, DC, PAT-APPL-6-290 264, 10 pp (Aug 5, 1981)

Key Words: Oscillators

An FET oscillator, including the means for controlling the gain of the oscillator to control its output level to thereby avoid limiting, and thus to reduce distortion of the oscillator output, is studied.

DYNAMIC TESTS
(Also see No. 1130)

82-1087
On Modal Analysis of Structures with Nonproportional Damping
M. Rades
Polytechnic Inst., Bucharest, Romania, Mécanique Appliquée, 26 (4), pp 605-622 (July/Aug 1981) 3 figs, 1 table, 14 refs

Key Words: Modal tests, Underdamping, Natural frequencies, Mode shapes

A method is presented for the experimental modal analysis of structures with nonproportional damping. It is a new version of the method of independent force distributions, combining the advantages of the techniques developed by Asher and Angelini. The only experimental data required are the complex response vectors to a set of linearly independent non-appropriated force vectors. Single station shaker forcing, applied in turn at a number of stations on the structure, can be used as well. Undamped natural frequencies, mode shapes and all modal parameters are obtained without subsequent excitation of pure modes. Limited results of preliminary numerical studies are presented as an illustration of one variant of the proposed analysis procedure.

82-1088
Qualification Vibration Test Report for SD 802 Materials Experiment
A.F. DiGiacomo
Materials Sciences Lab., Aerospace Corp., El Segundo, CA, Rept. No. TR-0081 (6950-05)-3, SD-TR-81-58, 41 pp (Aug 3, 1981)
AD-A105 321

Key Words: Vibration tests, Materials

The qualification vibration tests conducted for SD 802 Spacecraft Materials Experiment Hardware, NASA Experi-

ment No. M0003, are described. These tests were performed to demonstrate the structural integrity of the experiment modules when mounted in flight configuration.

82-1089
Time Domain Vibration Testing Techniques in Stochastic Environment -- Model Reference Adaptive System Approach

S.A.-R. Zaghlool
Ph.D. Thesis, Univ. of California, Berkeley, 108 pp (1981)
UM 8200316

Key Words: Vibration tests, Testing techniques, Time domain method, Stochastic processes

Digital schemes for the implementation of time domain vibration testing techniques which are capable of coping with the stochastic nature of their data have been studied. The schemes may either employ one-shot, accumulative or recursive solution strategies and they appear to have high noise rejection performance and yield consistent and accurate results. Main emphasis is given for families of recursive algorithms which have fast rate of convergence and based upon an integral adaptation mechanism with constant or decreasing gain and may, or may not, include proportional adaptation mechanism.

82-1090
A New Impulsive Loading Method of Studying the Viscoelastic Materials: Application to a Birefringent Material

J.P. Lallemand
Laboratoire de Mecanique des Solides, Universite de Poitiers, 40, avenue du Recteur Pineau, 86022 Poitiers Cedex, France, Mechanics Res. Comm., 8 (5), pp 309-318 (1981) 4 figs, 4 refs

Key Words: Testing techniques, Impact tests, Viscoelastic media, Shock wave propagation

It is well known that analysis of propagation of an axial shock in a semi-infinite viscoelastic rod leads to the determination of mechanical behavior of the material under the one-dimensional loading conditions. Experiment consists in measuring the same physical data in two points of the rod. Analysis of these measures allows the relaxation function or Young's complex modulus to be determined. A method proposed herein is a different one. It is used to obtain the same results by means of the knowledge of space distribution of the same physical data observed at two instants. An optical experimental device is presented that allows the propagating wave to be captured in the case of a birefringent viscoelastic material. In the same time, the theoretical basis is given. It consists in an analysis of propagating wave written in terms of Fourier transforms over space variable (the classical approach is to use the Fourier transforms over time). For this reason, the method proposed hereby is called "full field optical method" on the contrary to the "ponctual methods" quoted in references.

82-1091
Evaluation and Wind Tunnel Tests of the 4,000 lb (Normal-Force) Pitch/Yaw and Roll-Damping Stability Balance Systems for Measuring Direct, Cross, and Cross-Coupling Derivatives

T.D. Buchanan, S.M. Coulter, and E.J. Marquart
Arnold Engrg. Dev. Ctr., Arnold AFS, TN, Rept. No. AEDC-TR-80-12, 79 pp (Sept 1981)
AD-A105 122

Key Words: Dynamic tests, Test facilities, Wind tunnel testing, Aircraft

Dynamic balances were fabricated to perform pitch, yaw, and roll dynamic stability tests of aircraft or large missile models. The balances were designed to measure not only the direct derivatives but also cross and cross-coupling derivatives. The set of balances comprises a 4,000-lb (normal-force) roll and a 4,000-lb pitch/yaw forced-oscillation balance to measure the direct damping derivatives and a five-component can-type balance to measure the cross and cross-coupling derivatives attributable to pitch or yaw. Extensive laboratory investigations of the balances' static and dynamic response characteristics were performed before wind tunnel tests of a 1/9-scale F-16A model.

82-1092
Acoustic Emission from Concrete Specimens

P.F. Mlakar, R.E. Walker, and B.R. Sullivan
Structures Lab., Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. WES/MP/SL-81-26, 39 pp (Sept 1981)
AD-A105 416

Key Words: Dynamic tests, Acoustic emission, Concretes

Six monotonic and six cyclic load compression tests on 6- by 12-in. cylindrical concrete specimens were monitored

for acoustic emission. Fundamental data were collected and analyzed and the Kaiser effect was observed. The data are presented as counts versus events to aid in the identification of source characteristics. One multiaxial load (compression and tension) test was also monitored. The slope of counts versus event curve for this primarily tension test differed from those of the curves for the primarily compression test. This difference suggests that the source characteristics of concrete acoustic emissions can be empirically separated and identified.

82-1093

Application of Pulse Code Modulation (PCM) Technology to Aircraft Dynamics Data Acquisition

C.A. Detmer, C.J. Guenther, and J.H. Rixleben

McDonnell Aircraft Co., St. Louis, MO, Rept. No. AFWAL-TR-81-3017, 431 pp (Apr 1981)

AD-A104 775

Key Words: Test facilities, Dynamic tests, Data recorders, Aircraft

AFWAL/FIBG has a facility that provides dynamics data acquisition and analysis to support ground and flight testing on Air Force systems. This capability is limited by the current analog data acquisition technology to the acquisition of 12 data channels simultaneously of 40 to 50 dB dynamic range. This report documents a study conducted to obtain an optimum data acquisition and analysis system using PCM technology to provide simultaneous acquisition of 144 channels with 60 to 70 dB dynamic range. Implementation of this design will advance the state-of-the-art for acquisition of high bandwidth (20 KHz) dynamics data and will result in a significant reduction in the cost of flight tests.

SCALING AND MODELING

82-1094

Theory and Application of Experimental Model Analysis in Earthquake Engineering

H. Krawinkler and P.D. Moncarz

John A. Blume Earthquake Engrg. Ctr., Stanford Univ., CA, Rept. No. NSF/CEE-81037, 274 pp (June 1981)

PB82-122409

Key Words: Testing techniques, Model testing, Seismic response

The feasibility and limitations of small-scale model studies in earthquake engineering and practice are summarized. Emphasis is placed on dynamic modeling theory; a study of the mechanical properties of model materials; the development of model construction techniques; and an evaluation of the accuracy of prototype response prediction through model case studies on components and simple structures. The basics of similitude theory and its application to the modeling of dynamically excited structures are reviewed and similitude laws for various types of models are developed. Materials for modeling of steel and reinforced concrete structures are examined with regard to cyclic load effects. Systematic material testing procedures are developed for the investigation of alternative model materials. Also, problems encountered in the construction of models are identified and recommendations are suggested to correct them. The research demonstrates that model analysis can be used in many cases to obtain quantitative information on the seismic behavior of complex structures which cannot be analyzed confidently by conventional techniques.

DIAGNOSTICS

82-1095

On-Line Failure Detection of Vibrating Structures

S.G. Azevedo, J.V. Candy, and D.L. Lager

Lawrence Livermore Natl. Lab., CA, Rept. No. CONF-810918-1, 26 pp (May 27, 1981) (Presented at ASME Conf. on Mechanical Vibration and Noise, Hartford, CT, Sept 20, 1981)

UCRL-86099

Key Words: Diagnostic techniques, Failure detection, Digital techniques, Computer-aided techniques

Nondestructive evaluation of vibrating structures for failure detection is an area of interest at the Lawrence Livermore National Laboratory. Recent advances in signal processing and analysis of vibrating structures have been applied to this problem with promising results. The techniques used are recursive on-line algorithms which include stochastic models for noise sources. An experiment was designed to investigate the feasibility of signal processing procedures for failure detection. A given structure was excited and its shock response measured using an accelerometer. The response data was digitized and processed. This failure detection problem was approached from the stochastic estimation theory viewpoint. The structural model is characterized from experimental data. A nonlinear identification algorithm (using an extended Kalman filter) is utilized for estimating modal parameters from vibration data. Using this model of the structure, a signal processing estimator is designed to increase the output signal-to-noise ratio. The estimator is followed by a decision device to detect structural failures or anomalies.

The results of this feasibility study indicate reasonable performance of these techniques for model characterization and failure detection. Examples and graphical illustrations are presented. .

MONITORING

82-1096

Application of the Internal Friction Damping-Non-Destructive Evaluation Technique for Identification of Degradation and Failure of Shipboard Cargo Piping

L.L. Yeager, J.W. Miller, and R.G. Brasfield

Daedalean Associates, Inc., Woodbine, MD, Rept. No. LLY-7911-001-DTR, MA-RD-920-81059, 196 pp (July 1981)

PB82-108879

Key Words: Monitoring techniques, Nondestructive tests, Coulomb friction, Pipes (tubes), Shipboard equipment response

This report discusses the research concerning the technical feasibility of applying an Internal Friction Damping-Non-destructive Evaluation (IFD-NDE) technique to cargo piping systems. The specific application addresses the problem of accurately identifying pipe sections degraded sufficiently to warrant repair or removal in a cost effective manner utilizing the IFD-NDE technique. The research effort includes laboratory testing of new and used pipe samples, varying from four inches to sixteen inches nominal diameter; field testing of cargo piping sections; development of a computer integrated equipment package; and evaluation of the equipment relative to intrinsic safety regulations of Underwriters Laboratories, Inc. and the United States Coast Guard. A field demonstration of the technique application concluded the program effort. The report concludes the feasibility of applying the IFD-NDE technique to cargo piping sections and proposes a field equipment package and test scenario for the maritime industry.

82-1097

Flow-Induced Vibration Analysis of Oconee-2B OTSG Tubes. Final Report

J.C. Simonis and J.C. Brown

Nuclear Power Generation Div., Babcock and Wilcox Co., Lynchburg, VA, 127 pp (June 1981)

EPRI-NP-1888

Key Words: Monitoring techniques, Vibration measurement, Tubes, Boiler tubes, Nuclear power plants

The vibratory response of four tubes in the B loop of the once-through steam generator (OTSG) has been measured at the Oconee 2 nuclear power station during steady-state operation. The responses of the tubes were measured by biaxial accelerometers installed in the upper span of three tubes adjacent to a missing lane of tubes (open lane) and a biaxial accelerometer installed in one tube lane toward the interior of the tube bundle (off lane). Data were analyzed to identify displacement, frequency, and damping trends associated with normal operation. These trends were then used to relate normal, steady-state power levels to anomalous tube responses. Also, the displacement frequency and damping trends from this measurement program were compared to similar results from the measurement program conducted on the Three Mile Island OTSG.

82-1098

Development of Sensors and Instrumentation for the TM1-2 OTSG Tube Vibration Measurements Program

J.M. Anthony and J.S. Olszewski

Nuclear Power Generation Div., Babcock and Wilcox Co., Lynchburg, VA, 168 pp (June 1981)

EPRI-NP-1875

Key Words: Monitoring techniques, Vibration measurement, Tubes, Boiler tubes, Nuclear power plants

The Babcock and Wilcox Company installed sensors in a once-through steam generator in the Three Mile Island Unit 2 plant to determine the vibrational response of selected steam generator tubes under various operating conditions, both normal and transient. Additional external sensors provided data which were used with flow and operating condition data to permit correlation to the tube response. This program demonstrates the feasibility of installing biaxial accelerometers at various depths within steam generator tubes along with up to four weldable strain gages in a single tube at one elevation.

82-1099

On-Line Acoustic-Emission Monitoring of Fossil Power Plants: A Critical Assessment. Final Report

D.E. Leaver and D.O. Harris

Science Applications, Inc., Palo Alto, CA, 107 pp (June 1981)

EPRI-CS-1896

Key Words: Monitoring techniques, Acoustic emission, Fossil power plants, Power plants (facilities)

Acoustic emission technology as it applies to the incipient failure detection of fossil plant components is reviewed. Studies were made of the potential application of acoustic emissions to the detection of failures of rotating shaft systems: turbine generators, pumps, fans, and compressors. Particularly of interest in this review was the early detection of cracks in the turbine generator shaft. Also studied was the use of acoustic monitoring techniques for heat exchanger tube leaks, particularly water walls, superheaters, reheaters, and feedwater heaters. Each potential application is rated as to its payoff and its probability of success. Recommended R and D plans are presented for those areas which offer good chance of success and high payoff. An important conclusion of this work is that monitoring of turbine shaft cracking is possible and desirable, although an optimum system may require rotating sensors in the bore and telemetry signals to transfer the ultrasonic signals to the stationary environment. Acoustic monitoring of the tube leaks in high-pressure water or steam systems, such as water walls, superheaters, and feedwater heaters, is also perceived to be a viable and valuable technique.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

82-1100
Finite Element Analysis of Interacting Soil-Structure-Fluid Systems with Local Nonlinearities
M. Khalvati
Ph.D. Thesis, Univ. of California, Berkeley, CA, 215 pp (1981)
UM 8200161

Key Words: Interaction: soil-structure, Interaction: structure-fluid, Finite element technique

During the last decade, structural problems with large domains of interacting soil-structure-fluid have been the topic of many investigations where finite element solution techniques have been employed. Several finite elements are presented for idealization of fluids, joints, shear wave propagation and free-field excitation input. The fluid element is formulated in the displacement domain and accurately idealizes inviscid fluids. The element performs well under low frequency (sloshing) and high frequency (wave propagation) loads. Static problems which are critical for this type of problem can easily be handled using the presented fluid element. Spurious zero-energy modes present in traditional fluid elements are corrected. Thus, the element is stable for dynamic problems. A nonlinear joint element is developed for idealization of soil-structure interfaces and cracks. Examples are included in different sections to demonstrate some of the applications of the presented finite elements and solution techniques.

82-1101
Stability Analysis of Complex Dynamical Systems: Some Computational Methods
N.R. Sarabudla
Ph.D. Thesis, Iowa State Univ., 134 pp (1981)
UM 8128855

Key Words: Stability methods, Dynamic systems

Two new algorithms are developed to determine estimates for the domain of attraction of the equilibrium $x = 0$ of nonlinear systems described by systems of equations of the form $\dot{x} = f(x)$. One of these algorithms utilizes quadratic Lyapunov functions while the second algorithm makes use of norm Lyapunov functions. Analysis of the results obtained for specific examples demonstrates that these two algorithms yield estimates for the domain of attraction which are comparable to those obtained by existing methods; however, the present algorithms appear to be significantly more efficient than the existing algorithms. The relationship between the eigenvalues of the Jacobian and Lyapunov matrices is established, and then based on this relationship and computational experience, some conclusions are made about the effect of changes in the eigenvalues of the Jacobian matrix on the estimated domain of attraction.

82-1102
Transmitting Boundaries for Time-Harmonic Elastodynamics on Infinite Domains
H. Murakami, S. Shioya, R. Yamada, and J.E. Luco
Dept. of Mech. Engrg., Natl. Defense Academy, Yokosuka, Japan, Intl. J. Numer. Methods Engrg., 17 (11), pp 1697-1716 (Nov 1981) 9 figs, 3 tables, 18 refs

Key Words: Finite element technique, Elastodynamic response, Cavities

A finite element method with transmitting boundary is developed for time-harmonic elastodynamics on infinite domains. Only a finite inner domain needs to be discretized into conventional finite elements, while the effect of the exterior domain is simulated by introducing the transmitting boundary stiffness matrix on the degrees-of-freedom of the

transmitting boundary nodes. In order to incorporate the Sommerfeld radiation condition, the reciprocity relation on the transmitting boundary for the radiating elastodynamic state under consideration and the one which is induced by a finite number of point sources is used to calculate the transmitting boundary stiffness matrix. The effectiveness of the transmitting boundary technique has been demonstrated by solving the stress concentration problems of a homogeneous isotropic full space with a circular cylindrical cavity and of the one with a spherical cavity, which are subjected to plane incident waves, and the results are compared with the ones of the conventional FEM and the exact data.

82-1103
Improving the Accuracy of Computed Eigenvalues and Eigenvectors

J.J. Dongarra, C.B. Moler, and J.H. Wilkinson
Argonne Natl. Lab., Argonne, IL, Rept. No. ANL-81-43, 31 pp (July 1981)
DE81028480

Key Words: Eigenvalue problems

This paper describes a computational method for improving the accuracy of a given eigenvalue and its associated eigenvector. The method is analogous to iterative improvement for the solution of linear systems. An iterative algorithm using working precision arithmetic is applied to increase the accuracy of the eigenpair. The only extended precision computation is the residual calculation. The method is related to inverse iteration and to Newton's method applied to the eigenvalue problem.

82-1104
Analytical Selection of Masters for the Reduced Eigenvalue Problem

V.N. Shah and M. Raymund
E.G. & G. Idaho, Inc., Idaho Falls, ID, Intl. J. Numer. Methods Engrg., 18 (1), pp 89-98 (Jan 1982) 2 figs, 5 tables, 18 refs

Key Words: Eigenvalue problems

Masters are defined as the degrees-of-freedom that are retained in the reduced eigenvalue problem. Various qualitative guidelines to select masters are published in the literature, but it is difficult to apply them to complex structures. In this paper a computational algorithm to select masters for complex structures is presented. This algorithm is based on a guideline which assures that the associated Guyan reduction process is valid. This algorithm eliminates one degree-of-freedom at a time satisfying the guideline, and preserves lower frequencies in the reduced eigenvalue problem. The algorithm presented in this paper is used to select masters for four different structural models. The natural frequencies of the associated reduced eigenvalue problems are calculated and compared with those calculated from the full eigenvalue problems.

82-1105
Nonlinear Perturbations of Dynamical Systems with Bounded Inputs

S.P. Banks
Dept. of Control Engrg., Sheffield Univ., UK, Rept. No. RR-129, 13 pp (Oct 1980)
N81-30892

Key Words: Perturbation theory

Results regarding systems where the input is subjected to bounded restrictions are generalized to the case of nonlinear systems subjected to nonlinear perturbations by imposing certain restrictions on the unperturbed free system. The nonlinear variations of constants formula are discussed and used to obtain bounds on the system states. The application of this formula to obtain state bounds assuming a bounded control is presented, and a Lyapunov type approach to the same problem is discussed. A simple example is presented to illustrate the theory. It is shown that the two approaches bring out different aspects of the problem, but no direct comparison is attempted since taking norms in different ways leads to conservative results.

82-1106
Nonlinear Equations of Motion of Large Multidegree of Freedom Systems (Nichtlineare Bewegungsgleichungen grosser Mehrkörpersysteme)

W. Schiehlen
Institut B f. Mechanik, Univ. Stuttgart, W. Germany, Z. Flugwiss., 61 (9), pp 413-420 (Sept 1981) 2 figs, 14 refs
(In German)

Key Words: Equations of motion, Multidegree of freedom systems

In the dynamical analysis of nonlinear mechanical systems with many degrees of freedom even the derivation of the equation of motion is an essential problem. It is shown that

the equations of motion of holonomic multibody systems are strongly simplified by the application of Jourdain's principle. This results in a better understanding of symbolical equations of motion and a reduction of computation time.

MODELING TECHNIQUES

(Also see Nos. 933, 974)

82-1107

Solution Techniques for Large Eigenvalue Problems in Structural Dynamics

I.-W. Lee

Ph.D. Thesis, Univ. of Illinois at Urbana-Champaign, 109 pp (1981)

UM 8127629

Key Words: Eigenvalue problems, Natural frequencies, Mode shapes, Continuous systems

This study deals with the determination of eigenvalues and eigenvectors of large algebraic systems. In particular, the methods developed are applicable to finding the natural frequencies and modes of vibration of large structural systems such as frames or continuous systems discretized in some way. For distinct eigenvalues the method is an application of the modified Newton-Raphson method that turns out to be more efficient than the standard competing schemes. It is also more efficient than the Robinson-Harris technique, which makes use of the ordinary Newton-Raphson method.

82-1108

Random Vibration of Hysteretic, Degrading Systems

T.T. Baber and Y.-K. Wen

Civil Engrg. Dept., Univ. of Virginia, Charlottesville, VA, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1069-1087 (Dec 1981) 13 figs, 1 table, 28 refs

Key Words: Random vibration, Seismic response, Hysteretic damping

A differential equation model for hysteretic systems with strength, stiffness or combined degradation is presented. Solution under white noise, Kanai filtered white noise and temporally modulated filtered white noise is obtained by equivalent linearization, without recourse to the Krylov-Bogoliubov approximation typically required for hysteretic systems. Resulting zero time lag covariance response matrices agree well with simulated solutions at all excitation levels. First passage predictions are nonconservative, because of the non-Gaussian character of the response.

82-1109

Modelling of Soil-Structure Interaction by Finite and Infinite Elements

F.J. Medina-Melo

Ph.D. Thesis, Univ. of California, Berkeley, CA, 53 pp (1981)

UM 8200207

Key Words: Mathematical models, Interaction: soil-structure, Plates, Circular plates, Harmonic excitation

A direct method for solving dynamically excited structures on elastic semi-infinite media is suggested as an improvement over available approaches. The method consists in modeling the near field with finite elements and the far field with infinite elements. The method falls within the framework of the classical finite element method and preserves its flexibilities. The key to the success of the proposed method is the proper definition of the infinite element shape functions. The requirements that these shape functions must fulfill are clearly outlined.

82-1110

Dynamics of a Chain of Flexible Bodies

R.P. Singh

Ph.D. Thesis, The Univ. of Alabama in Huntsville, AL, 134 pp (1981)

UM 8128324

Key Words: Mathematical models, Equations of motion

A mathematical modeling technique is developed for a space structure idealized as a collection of flexible bodies in a chain configuration. The methodology employed in the derivation does not require the presence of a rigid body in the chain. The contiguous bodies are permitted to undergo large relative rotations. The Lagrange's form of D'Alembert's principle is adopted to derive the equations of motion. The mathematical foundations of the quasi-coordinates are explored and it is shown that they emerge naturally from a variational principle. It is shown that the Tisserand frame follows the deformable body in an optimal manner. This frame has a well defined motion in an inertial reference frame and is suitable for use in conjunction with linear structural theory.

82-1111

Three-Dimensional Hybrid Modelling of Soil-Structure Interaction

S. Gupta, J. Penzien, T.W. Lin, and C.S. Yeh
Dept. of Civil Engrg., Univ. of California, Berkeley, CA, Earthquake Engrg. Struc. Dyn., 10 (1), pp 69-87 (Jan-Feb 1982) 16 figs, 25 refs

Key Words: Mathematical models, Interaction: soil-structure, Finite element technique, Substructuring methods

A three-dimensional hybrid model for the analysis of soil-structure interaction under dynamic conditions is developed which takes advantage of the desirable features of the finite element and substructure methods and which minimizes their undesirable features. The modeling is achieved by partitioning the total soil-structure system into a near-field and a far-field with a hemispherical interface. The near-field, which consists of the structure to be analyzed and a finite region of soil around it, is modeled by finite elements. The semi-infinite far-field is modeled by distributed impedance functions at the interface which are determined by system identification methods. Numerical results indicate that the proposed model makes possible realistic and economical assessment of three-dimensional soil-structure interaction for both surface and embedded structures.

NUMERICAL METHODS

82-1112

Dynamic Soil-Structure Interaction by Numerical Laplace Transform

G.V. Narayanan and D.E. Beskos
Southwest Res. Inst., 6220 Culebra Rd., San Antonio, TX 78284, Engrg. Structures, 4 (1), pp 53-62 (Jan 1982) 9 figs, 2 tables, 25 refs

Key Words: Interaction: soil-structure, Seismic excitation, Laplace transformation

The dynamic response of general discrete and certain continuous linear systems to earthquake excitation including the effect of soil-structure interaction is obtained with the aid of the Laplace transform with respect to time. Application of the Laplace transform on the finite element equations of motion for a discrete system, directly or in conjunction with modal analysis, reduces them to a system of algebraic equations which are solved numerically in the transform domain. The Laplace transformed equations of motion for beam structures with a continuous distribution of mass are constructed in a finite element fashion with the aid of transformed dynamic stiffness coefficients and are solved numerically to yield the transformed solution. The system response in both cases is obtained by a numerical inversion of the transformed solution. Illustrative numerical examples are presented and the advantage-disadvantages of the Laplace transform technique are discussed.

82-1113

Simultaneous Relaxation in Structural Dynamics

D.P. Flanagan and T. Belytschko
Dept. of Civil Engrg., Northwestern Univ., Evanston, IL 60201, ASCE J. Engrg. Mechanics Div., 107 (6), pp 1039-1055 (Dec 1981) 7 figs, 6 tables, 16 refs

Key Words: Relaxation method (mathematics), Dynamic response

The applicability of relaxation methods to implicit integration of structural dynamics problems is investigated. It is shown that although Jacabi interaction is not competitive with explicit methods, conjugate gradient second order acceleration leads to schemes which are quite efficient, and its effectiveness is uneffected by the use of a consistent mass. For methods that require eigenvalue estimates, bounds are obtained by examining a single element and use of a theorem proved herein that the spectra of assembled positive definite matrices are always bounded by the unassembled element matrix. An energy based error criterion is developed for those methods.

STATISTICAL METHODS

(Also see No. 986)

82-1114

An Introduction to Statistical Energy Analysis of Structural Vibration

J. Woodhouse
Topexpress Ltd., 1 Portugal Pl., Cambridge CB5 8AF, UK, Appl. Acoust., 14 (6), pp 455-469 (Nov-Dec 1981) 3 figs, 6 refs

Key Words: Statistical energy analysis

The ideas of the approach to vibration analysis called Statistical Energy Analysis (SEA) are explored without going into great technical detail. The aim of this description is to give guidance to those with particular vibration problems who may ask whether they should be using SEA and, if so, what expectations they should have of it. In the first section, SEA in its most common form is illustrated by the simplest example. In the second section, the question of the underlying assumptions of SEA is considered by a simple and

apparently novel approach. This discussion also gives some information on possible methods of measuring the SEA parameters in a given problem and deciding whether a SEA model is indeed appropriate for that problem. We also attempt to give guidance on how SEA should be applied to a given problem, especially how the system under study should be divided up into subsystems.

PARAMETER IDENTIFICATION

(Also see No. 986)

82-1115

A Layering Approach to System Identification: Application to Dynamics of Linear Structures with Measured Eigenproperties

A.K.-O. Chou

Ph.D. Thesis, Univ. of California, Berkeley, CA, 244 pp (1981)
UM 8200056

Key Words: System identification techniques, Linear systems

After presenting a general view of system identification in relation to structures, the distinctive characteristics of structural systems are discussed, followed by a summary of previous work utilizing measured eigenproperties as data. The Group Method of Data Handling (GMDH) in polynomial regression, by which this study is motivated, is then described and illustrated by a simple example to prepare for the discussion of its adaptation to the proposed algorithm. GMDH derives from a non-uniqueness concept of solution to engineering problems. At every layer of the solution process, a subset of solutions is produced, from which elements are selected for advancement to a higher layer. The results of the numerical experimentation indicate that: the algorithm is inherently stable; variation in random selection of parameter combinations affects the convergence rate but not the converged results; best convergence is achieved by partitioning the parameters into two groups in the 1st layer and encompassing the complete set in the 2nd layer; and with uncorrupted data, all the parameters converge with zero error. Random noise in the measured data induces bias in the converged solution, as expected. The proposed algorithm claims no superiority over other existing methods. It is developed to shed some light on the non-uniqueness concept of problem solving.

82-1116

Identification of Systems Composed of Linear Dynamic and Static Nonlinear Elements

S.A. Billings and S.Y. Fakhouri

Dept. of Control Engrg., Sheffield Univ., UK, Rept. No. RR-131, 41 pp (Nov 1980)
N81-30858

Key Words: System identification technique

Identification of nonlinear systems which can be represented by combinations of linear dynamic and static nonlinear elements are considered. Results based on correlation analysis are combined to provide a unified treatment for this class of systems. Systems composed of cascade, feedforward, feedback and multiplicative connections of linear dynamic and zero memory nonlinear elements can be identified in terms of the individual component subsystems from measurements of the system input and output only.

82-1117

Bilinear System Identification by Block Pulse Functions

Y.G. Jan and K.M. Wong
Dept. of Elect. Engrg., Tech. Univ. of Nova Scotia, Halifax, Nova Scotia, Canada B3J 2X4, J. Franklin Inst., pp 349-359 (1981) 2 tables, 6 refs

Key Words: Parameter identification technique, Block pulse functions

A new method is employed to identify the unknown parameters of a bilinear system. This method expands the system input and output by block pulse functions and reduces the original identification problem to an algebraic form. Furthermore, the dyad formed by block pulse functions and its integral are in diagonal forms, whereas the integration of the "triple-product" matrix can be reduced to the upper triangular form. Consequently, only very few calculations are required to find the solution for the algebraic equation. Two examples are given to show that the use of this method is considerably more economical in computation time than the use of Walsh function expansion.

82-1118

Coupled Oscillators as a Model for Nonlinear Parametric Excitation

C.A. Holmes and R.H. Rand
Ctr. for Appl. Mathematics, Cornell Univ., Ithaca, NY, Mechanics Res. Comm., 8 (5), pp 263-268 (1981) 1 fig, 9 refs

Key Words: Parametric excitation, Mathieu functions, Perturbation theory

In this paper the behavior of three conservative systems exhibiting parametric excitation are compared: the linear Mathieu equation a nonlinear Mathieu equation and an autonomous system of two coupled nonlinear oscillators. The comparison is based on approximate Poincaré maps obtained by various perturbation methods involving near identity transformations.

OPTIMIZATION TECHNIQUES

82-1119

Optimization with Frequency Constraint

W.R. Spillers, S. Singh, and R. Levy

Dept. of Civil Engrg., Rensselaer Polytechnic Inst., Troy, NY 12181, ASCE J. Struct. Div., 107 (12), pp 2337-2347 (Dec 1981) 4 figs, 9 refs

Key Words: Optimization, Minimum weight design, Frequency constraints

The use of allowable stress algorithms for a simple structural optimization problem with a single frequency constraint and a constant mass matrix is discussed. The mathematical properties of the eigenvalue problem are reviewed. An allowable stress algorithm is stated and its properties discussed. Two simple examples are presented. The primary concern of this paper lies in placing allowable stress-type algorithms within the mathematical programming literature.

COMPUTER PROGRAMS

82-1120

BEOS, a Program for Computing Buckling Loads and Natural Vibrations of Eccentrically Orthotropic Shells

K. Rohwer

Deutsche Forschungs- und Versuchsanstalt fuer Luftund Raumfahrt e.V., Brunswick, Fed. Rep. Germany, Rept. No. DFVLR-MITT-81-07, 56 pp (Mar 1981)

N81-32562

Key Words: Computer programs, Plates, Shells, Natural frequencies

A users manual for a FORTRAN 4 program for bifurcation buckling loads and natural vibrations of plates and shells is presented. Different wall configurations may be treated, including walls built of several orthotropic layers which may be eccentrically stacked. One of these layers may even be relatively weak in transverse shear so as to describe a sandwich behavior. Discrete stiffeners can also be taken into account. All input formats are given and algorithms used by the program are described.

82-1121

User's Manual for a Computer Program to Calculate Discrete Frequency Noise of Conventional and Advanced Propellers

R.M. Martin and F. Farassat

NASA Langley Res. Ctr., Hampton, VA, Rept. No. NASA-TM-83135, L-14374, 90 pp (Aug 1981)

N81-32966

Key Words: Computer programs, Propeller noise

A user's manual is presented for a computer program for the calculation of discrete frequency noise of conventional and advanced propellers. The structure of the program and the subroutines describing the input functions are discussed. Input variables and their default values and the variables in the output data sheet are defined. Two versions of the program are available. These differ only in the graphic output capability. One version has only printed output capability. A second version with extensive graphic output capability is available for the computer system at Langley. This manual includes four detailed examples of both the printed and graphic outputs. These examples may be reproduced by users to check their code on their computer system.

82-1122

Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs under Blast Loading (CBARCS), Users Guide

J.M. Ferritto, R.M. Wamsley, and P.K. Senter

Army Engineer Waterways Experiment Station, Vicksburg, MS, Rept. No. WES-INSTRUCTION-K-81-6, 84 pp (Mar 1981)

AD-A104 253

Key Words: Computer programs, Slabs, Reinforced concrete, Blast resistant structures

This report is a user's guide for CBARCS, a computer program for optimum nonlinear dynamic design of reinforced concrete slabs under blast loading. Given the explosive parameters and geometry of the slab, CBARCS computes the blast environment and the structural resistance, mass, and

stiffness of the slab and solves for the dynamic response. The program contains optimization subroutines that provide for automatic optimum design of least-cost structural slabs. CBARCS will assist engineers in the design and analysis of facilities that are intended to contain the effects of accidental explosions.

82-1123
CRASH2 Maintenance. Volume 1: Description of Results
T. Oppenheim
Wilson-Hill Associates, Inc., Washington, DC, Rept. No. DOT-HS-805 948, 250 pp (May 1981)
PB81-246167

Key Words: Collision research (automotive), Computer programs, CRASH (computer program)

The document is a comprehensive report on a number of tasks related to several versions of the CRASH computer model of automobile collisions. A series of activities were performed designed to maintain, debug, and update several versions of CRASH.

82-1124
CRASH2 Maintenance. Volume II: Listings of Test Runs
T. Oppenheim
Wilson-Hill Associates, Inc., Washington, DC, Rept. No. DOT-HS-805 949, 681 pp (May 1981)
PB81-246175

Key Words: Collision research (automotive), Computer programs, CRASH (computer program)

This volume contains complete computer listings for 56 test runs of several versions of the CRASH2, CRASH2A and CRASH3 programs. A separate summary of the test input data is included.

82-1125
List of Soils, Soil-Structure Interaction and Other Related Computer Programs Available for LMVD Engineers
N. Radhakrishnan and P.K. Senter
Army Engineer Waterways Experiment Station, Vicksburg, MS
AD-A103 384

Key Words: Interaction: soil-structure, Computer programs

This report presents a list of soils, soil-structure interaction, and other related computer programs available for engineers of the Lower Mississippi Valley Division. Programs for use in the following subject areas are listed: T-walls; slope stability; piles; sheet piles, and cells; seepage; stress computation, settlement, and consolidation; piezometer data; instrumentation and laboratory data; plotting programs; finite element and finite difference methods; earthquakes and dynamics; and others. Also included are abstracts of some of the listed programs.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

82-1126
Recent Developments in Acoustic Intensity Measurement
Proc. of an International Congress, Senlis, France, Sept 30 - Oct 2, 1981; Avail: Centre Technique des Industries Mécaniques (CETIM), B.P. 67, F-60304 Senlis, France

Key Words: Proceedings, Acoustic emission, Measurement techniques

Forty papers were presented at this conference attended by representatives from forty countries. The conference included the following sessions: measurement principles, inherent errors; instrumentation; analysis of sound fields; characterization of sound sources; sound power determination; propagation in structures and fluids.

TUTORIALS AND REVIEWS

82-1127
Twenty-Five Years of Stapp Car Crash Conferences
J.P. Stapp

United States Air Force, Retired, SAE Paper No. 811011

Key Words: Collision research (automotive), Reviews

A historical review covering twenty-six years during which there were twenty-four meetings for field demonstrations and presentation of scientific papers. Twenty volumes of Proceedings were produced, consecutively numbered from Fifth to Twenty-Fifth from 1961 through 1981. The first meeting was at Holloman Air Force Base on May 17, 1955 in response to a request by Don Blanchard of the Society of Automotive Engineers for a tour of facilities and field demonstrations by the Aeromedical Field Laboratory relating to automotive crash research, for the benefit of the newly organized SAE Committee on Motor Vehicle Seat Belts and invited guests. The evolution of the Stapp Car Crash Conferences in terms of organization and program development is traced. Contributions to automotive safety research resulting from the Car Crash Conferences are discussed.

82-1128

Dynamic Stability Parameters

Advisory Group for Aerospace Res. and Dev., Neuilly-sur-Seine, France, Rept. No. AGARD-LS-114, 404 pp (May 1981) (Lecture series presented at NASA Ames Research Center, Mar 2-5, 1981, Moffett Field, CA and von Karman Inst., Mar 16-19, 1981, Rhode-Saint-Genese, Belgium)
AD-A103 764

Key Words: Reviews, Dynamic stability

The contents of the report include: aerodynamic mathematical modeling - basic concepts; impact of high-alpha aerodynamics on dynamic stability parameters of aircraft and missiles; review of techniques for determination of dynamic stability parameters in wind tunnels; direct forced-oscillation techniques for the determination of stability derivatives in wind-tunnels; wind-tunnel measurement of aerodynamic derivatives using flexible-sting rigs; rotary and magnus balances; curved-flow, rolling flow and oscillatory pure-yawing wind tunnel test methods for determination of dynamic stability derivatives; support interference; applications of half-model technique in dynamic stability testing; determination of aircraft dynamic stability and control parameters from flight testing; estimation of dynamic stability parameters from drop model flight tests; analytical determination of dynamic stability parameters; aeroelasticity, including dynamic effects of separated flow; control derivatives; sensitivity of aircraft motion to cross-coupling and acceleration derivatives; some applications of aerodynamic formulations to problems in aircraft dynamics; applications of dynamic stability parameters to problems in aircraft dynamics; and application to missile dynamics.

82-1129

Noise Pollution in Textile Mills. 1975 - November, 1981 (Citations from World Textile Abstracts)

NTIS, Springfield, VA, 95 pp (Nov 1981)
PB82-855719

Key Words: Bibliographies, Noise reduction, Industrial noise, Textile looms

Reports are cited which discuss techniques and methods for suppressing noise created by mechanical processes necessary to the textile industry. Noise level regulations created and enforced by federal agencies, attenuation methods for combing, shedding, weaving and spinning processes, and economic ramifications of less noisy textile plants are included. Noise reduction techniques such as work area planning, plant construction design changes, machine design alterations, and hearing protection devices are considered. (Contains 137 citations fully indexed and including a title list.)

82-1130

Acoustic Holography. 1964 - September, 1981 (Citations from the NTIS Data Base)

NTIS, Springfield, VA, Rept. for 1964 - Sept 1981, 196 pp (Nov 1981)
PB82-801382

Key Words: Acoustic holography, Bibliographies, Nondestructive tests

Aspects of acoustic holography are covered in this bibliography of federally-funded research. Theory, equipment design, uses, and imaging techniques are presented. The applications include underwater and underground object locating, structural geology and tectonics, sonar imaging, non-destructive testing, antenna radiation patterns, nuclear reactor inspection, remote sensing, and use in medical examinations. (This updated bibliography contains 190 citations, 24 of which are new entries to the previous edition.)

82-1131

A Comprehensive Bibliography of Literature on Helicopter Noise Technology

A.M. Carter, Jr.

HOPE Associates, Inc., Washington, DC, Rept. No. FAA/EE-81-4, 116 pp (June 1981)
AD-A103 331

Key Words: Helicopter noise, Bibliographies

This bibliography, covering the period 1975 through calendar 1980, also provides abstracts on literature that appear to make a significant contribution to the field of helicopter noise technology. The helicopter is recognized as a complex noise generator, with significant contributions from the rotors, the engine and the gearbox. Progress continues to be made in the noise areas of: formulations, math models and analytical procedures; noise prediction methodology; noise reduction techniques; and subjective response to helicopter noise. The body of information, data and knowledge has use in many applications, including the reduction of helicopter noise in a cost effective manner and in minimizing annoyance to the civil populace.

AUTHOR INDEX

TECHNICAL NOTES

T.G. Tsicnias and G.L. Hutchinson
Note on the Perturbation Analysis of the Mode Shapes of Torsionally Coupled Buildings
Earthquake Engrg. Struc. Dynam., 10 (1), pp 171-174 (Jan-Feb 1982) 4 tables, 5 refs

J.C. Ortega and K.D. Kryter
Comparison of Aircraft and Ground Vehicle Noise Levels in Front and Backyards of Residences
J. Acoust. Soc. Amer., 71 (1), pp 216-217 (Jan 1982) 1 fig, 2 tables, 1 ref

P.B. Davidson and O.L. Vance
Tapered Circular Beam as Dynamic Vibration Absorber
J. Acoust. Soc. Amer., 71 (1), pp 212-215 (Jan 1982) 3 figs, 1 table, 10 refs

M. Baruch
Correction of Stiffness Matrix Using Vibration Tests
AIAA J., 20 (3), pp 441-442 (Mar 1982) 7 refs

R.R. Craig, Jr. and Y.-T. Chung
Generalized Substructure Coupling Procedure for Damped Systems
AIAA J., 20 (3), pp 442-444 (Mar 1982) 1 fig, 1 table, 3 refs

J.S. Tomar, D.C. Gupta, and R.K. Sharma
Torsional Vibrations of Orthotropic Conical Shells
AIAA J., 20 (3), pp 444-446 (Mar 1982) 3 figs, 5 refs

R. Dungar
Imposed Force Summation Method for Non-Linear Dynamic Analysis
Earthquake Engrg. Struc. Dynam., 10 (1), pp 165-170 (Jan-Feb 1982) 3 figs, 11 refs

E. Gartenberg, H. Wolff, and A. Gany
Testing of Ablative Elastomeric Insulators
Israel J. Tech., 19 (1-2), pp 75-79 (1981) 5 figs, 2 tables, 4 refs

Y. Goldman and D. Xieu
Double Chamber Pulsating Combustion System
Israel J. Tech., 19 (1-2), pp 71-74 (1981) 3 figs, 2 refs

T.F. Raske
Question of Dynamics of Mass Acceleration on Elastic Members
J. Acoust. Soc. Amer., 71 (1), pp 207-211 (Jan 1982) 3 figs, 10 refs

CALENDAR

JUNE 1982

7-11 Passenger Car Meeting [SAE] Dearborn, MI *(SAE Hqs.)*

JULY 1982

1-3 2nd Intl. Conf. on Applied Modeling and Simulation [IASTED] Paris, France *(ASME, 16 avenue de Grange Blanche, 69160 Tassin la Demi Lune, France)*

13-15 'Environmental Engineering Today' Symposium and Exhibition [SEE] London, England *(SEECO 82 Organisers, Owles Hall, Buntingford, Herts. SG9 9PL, England · Tel: Royston (0763) 71209)*

19-21 12th Intersociety Conference on Environmental Systems [SAE] San Diego, CA *(SAE Hqs.)*

AUGUST 1982

15-19 Computer Engineering Conference and Exhibit [ASME] San Diego, CA *(ASME Hqs.)*

16-19 West Coast International Meeting [SAE] San Francisco, CA *(SAE Hqs.)*

SEPTEMBER 1982

12-14 Petroleum Workshop and Conference [ASME] Philadelphia, PA *(ASME Hqs.)*

12-15 1982 Design Automation Conference [ASME] Washington, DC *(Prof. Kenneth M. Ragsdell, Purdue Univ., School of Mech. Engrg., West Lafayette, IN 47907 · (317) 494-8607)*

13-16 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI *(SAE Hqs.)*

OCTOBER 1982

4-6 Convergence '82 [SAE] Dearborn, MI *(SAE Hqs.)*

4-6 Lubrication Conference [ASME] Washington, DC *(ASME Hqs.)*

4-7 Symposium on Advances and Trends in Structural and Solid Mechanics [George Washington University and NASA Langley Res. Ctr.] Washington, DC *(Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Res. Ctr., Hampton, VA 23665 · (804) 827-2897)*

5-7 Western Design Engineering Show [ASME] Anaheim, CA *(ASME Hqs.)*

12-15 Stapp Car Crash Conference [SAE] Ann Arbor, MI *(SAE Hqs.)*

17-21 Power Generation Conference [ASME] Denver, CO *(ASME Hqs.)*

25-28 Advances in Dynamic Analysis and Testing [SAE Technical Committee G-5] 1982 SAE Aerospace Congress & Exposition, Anaheim, CA *(Roy W. Mustain, Rockwell Space Systems Group, Mail St. AB97, 12214 Lakewood Blvd., Downey, CA 90421)*

25-28 1982 SAE Aerospace Congress and Exposition [SAE] Anaheim, CA *(SAE Hqs)*

26-28 53rd Shock and Vibration Symposium [Shock and Vibration Information Center, Washington, DC] Danvers, MA *(Henry C. Pusey, Director, SVIC, Naval Res. Lab., Code 5804, Washington, DC 20375)*

NOVEMBER 1982

8-10 Intl. Modal Analysis Conference [Union College] Orlando, FL *(Prof. Raymond Eisenstadt, Union College, Graduate and Continuing Studies, Wells House, 1 Union Ave., Schenectady, NY 12308 · (518) 370-6288)*

8-12 Acoustical Society of America, Fall Meeting [ASA] Orlando, FL *(ASA Hqs.)*

8-12 Truck Meeting & Exposition [SAE] Indianapolis, IN *(SAE Hqs.)*

14-19 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Phoenix, AZ *(ASME Hqs.)*

DECEMBER 1982

14-16 11th Turbomachinery Symposium [Texas A&M University] Houston, TX *(Turbomachinery Labs., Dept. of Mechanical Engineering, Texas A&M University, College Station, TX 77843 · (713) 845-7417)*

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AFIPS: American Federation of Information Processing Societies
210 Summit Ave., Montvale, NJ 07645

AGMA: American Gear Manufacturers Association
1330 Mass Ave., N.W.
Washington, D.C.

AHS: American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA: American Institute of Aeronautics and Astronautics, 1290 Sixth Ave.
New York, NY 10019

AIChE: American Institute of Chemical Engineers
345 E. 47th St.
New York, NY 10017

AREA: American Railway Engineering Association
59 E. Van Buren St.
Chicago, IL 60605

ARPA: Advanced Research Projects Agency

ASA: Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE: American Society of Civil Engineers
345 E. 45th St.
New York, NY 10017

ASME: American Society of Mechanical Engineers
345 E. 45th St.
New York, NY 10017

ASNT: American Society for Nondestructive Testing
914 Chicago Ave.
Evanston, IL 60202

ASQC: American Society for Quality Control
161 W. Wisconsin Ave.
Milwaukee, WI 53203

ASTM: American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

CCCAM: Chairman, c/o Dept. ME, Univ. Toronto,
Toronto 5, Ontario, Canada

ICF: International Congress on Fracture
Tohoku Univ.
Sendai, Japan

IEEE: Institute of Electrical and Electronics Engineers
345 E. 47th St.
New York, NY 10017

IES: Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IFToMM: International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE: Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA: Instrument Society of America
400 Stanwix St.
Pittsburgh, PA 15222

ONR: Office of Naval Research
Code 40084, Dept. Navy
Arlington, VA 22217

SAE: Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

SEE: Society of Environmental Engineers
6 Conduit St.
London W1R 9TG, UK

SESA: Society for Experimental Stress Analysis
21 Bridge Sq.
Westport, CT 06880

SNAME: Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE: Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC: Shock and Vibration Information Center
Naval Research Lab., Code 5804
Washington, D.C. 20375

URSI-USNC: International Union of Radio Science -
U.S. National Committee
c/o MIT Lincoln Lab.
Lexington, MA 02173

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SUMMARY COVER SHEET
53rd SHOCK AND VIBRATION SYMPOSIUM
DANVERS, MA, 26-28 OCTOBER 1982
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53rd SHOCK AND VIBRATION SYMPOSIUM
DANVERS, MA, 26-28 OCTOBER 1982

SUBMISSION DEADLINE: 15 September 1982
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